

CAPRICE: Pilot Plant Data Validation

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Contents

- Description of pilot plants
- Test run selection criteria and procedure
- Simulators tested
- Common simulation basis
- Comparative simulation results
- Summary

Acknowledgements

Pilot plants studied

ITT Stuttgart Miniplant

University of Regina, ITC

DONG Energy, CASTOR Plant

NTNU/SINTEF, Laboratory Pilot



Wash water section

Packing type	Diameter	Height
N/A	N/A	N/A
Mellapak252Y	1.1m	3m
Flexipac700Y	0.33m	2.93m
Mellapak250Y	0,125	0.42m

Absorber

Packing type	Diameter	Height
Mellapak250Y	0.15m	4.36m
IMTP50	1.1m	17m
Flexipac700Y	0.33m	7.05m
Mellapak250Y	0.125m	4.2m

Stripper

Packing type	Diameter	Height
Mellapak250Y	0.1m	3.89m
IMTP50	1.1m	10m
Flexipac700Y	0.33m	9.97m
Mellapak250Y	0.125m	2.52m

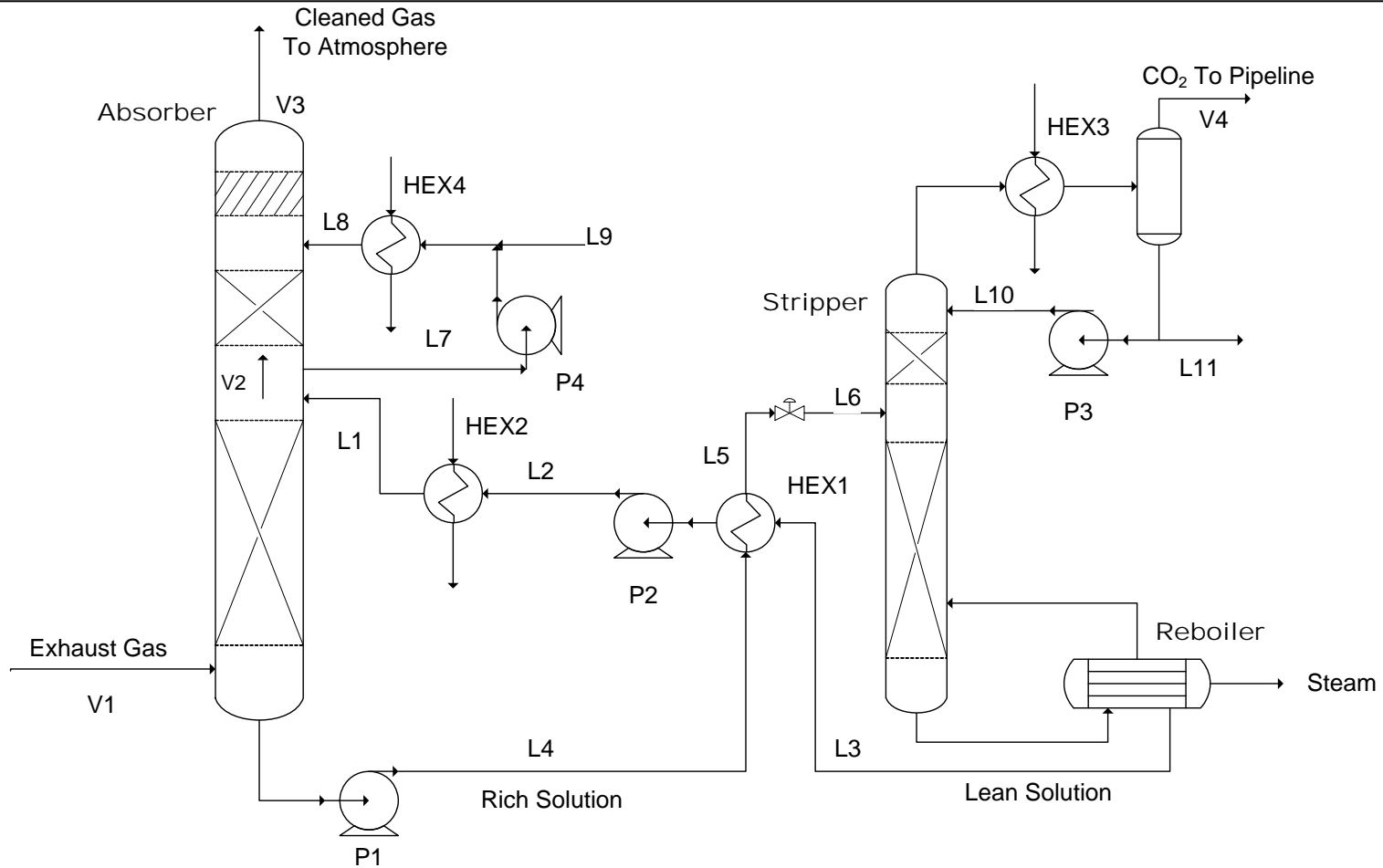
NTNU/SINTEF

DONG

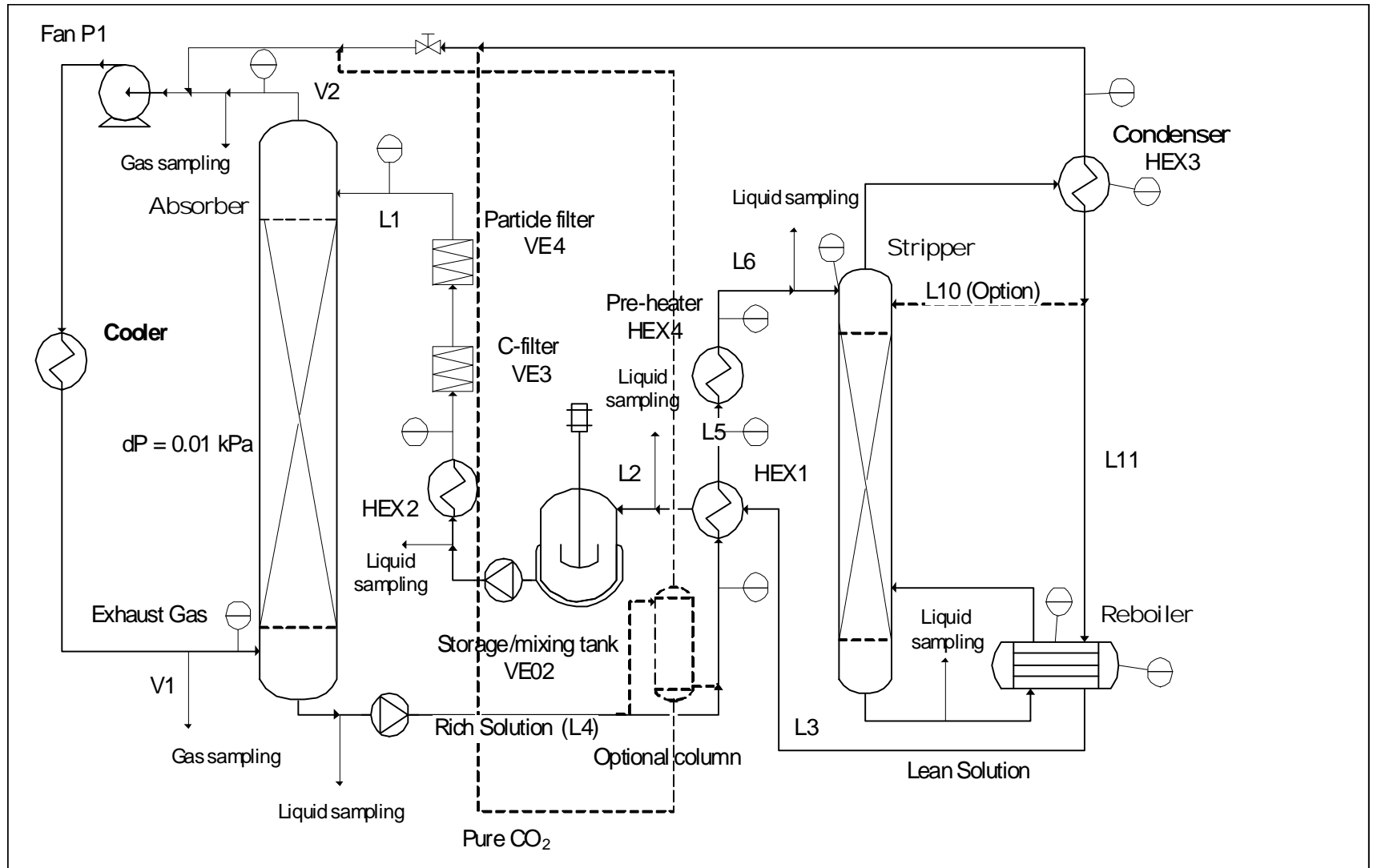
ITC, REGINA

ITT, STUTTGART

Flow sheet of pilot at DONG Energy, University of Regina ITC, and ITT Stuttgart(now at University of Kaiserslautern)



Flow sheet of pilot at NTNU/SINTEF



Selection criteria for runs to be simulated

- Mass transfer consistency
- Heat balance consistency
- Spread in operating conditions
 - Lean loading
 - Reboiler duty
 - Liquid flowrate
 - Inlet CO₂ concentration

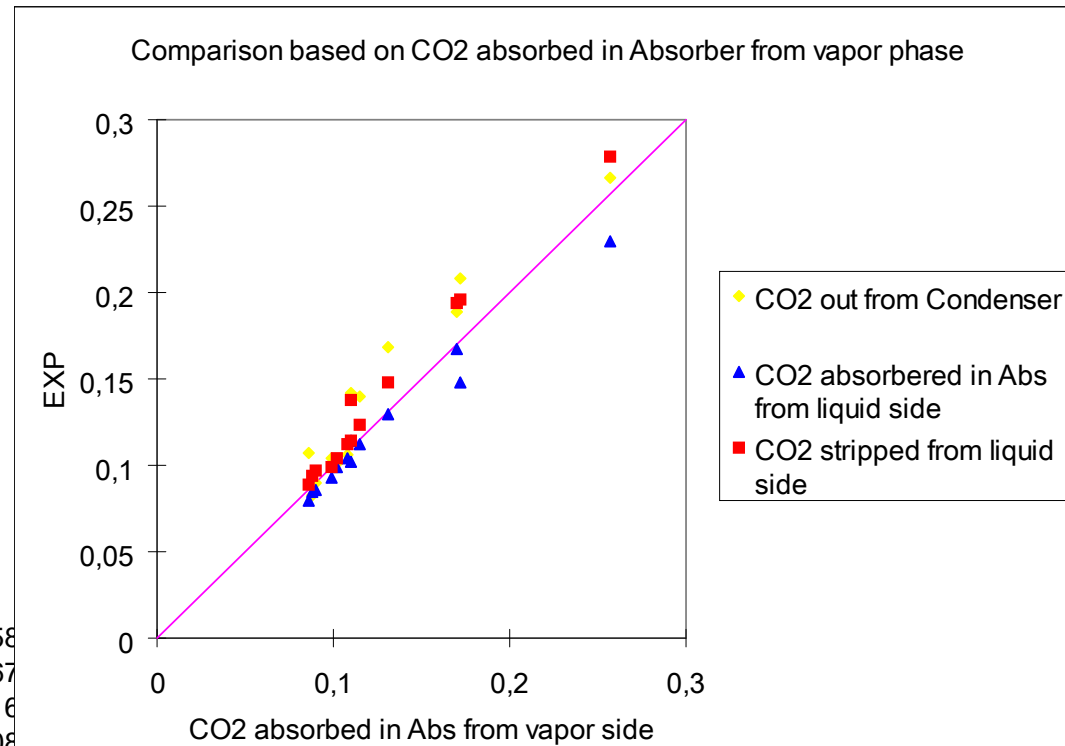
Example: NTNU/SINTEF pilot

Spread and consistency in mass transfer rate

Mass transfer

- 1 CO2 absorbered in Abs from Vapor phase
- 2 CO2 out from Condenser
- 3 CO2 absorbered in Abs from Liquid phase
- 4 CO2 stripped from liquid phase

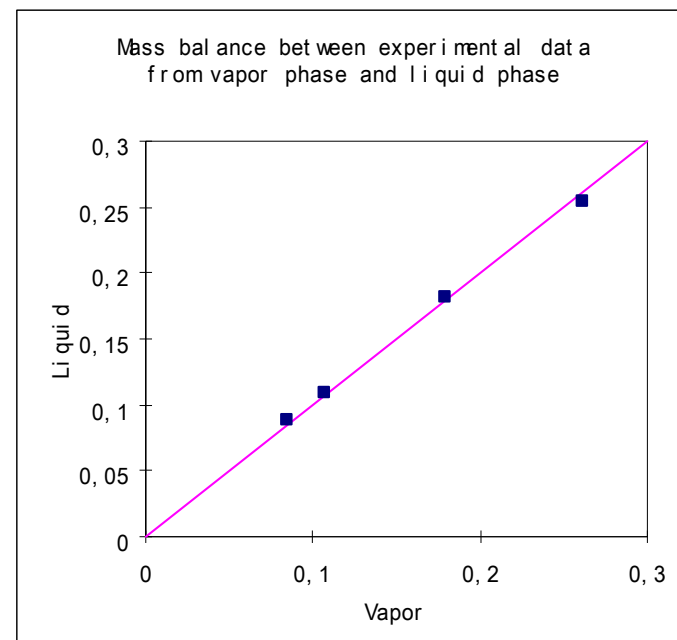
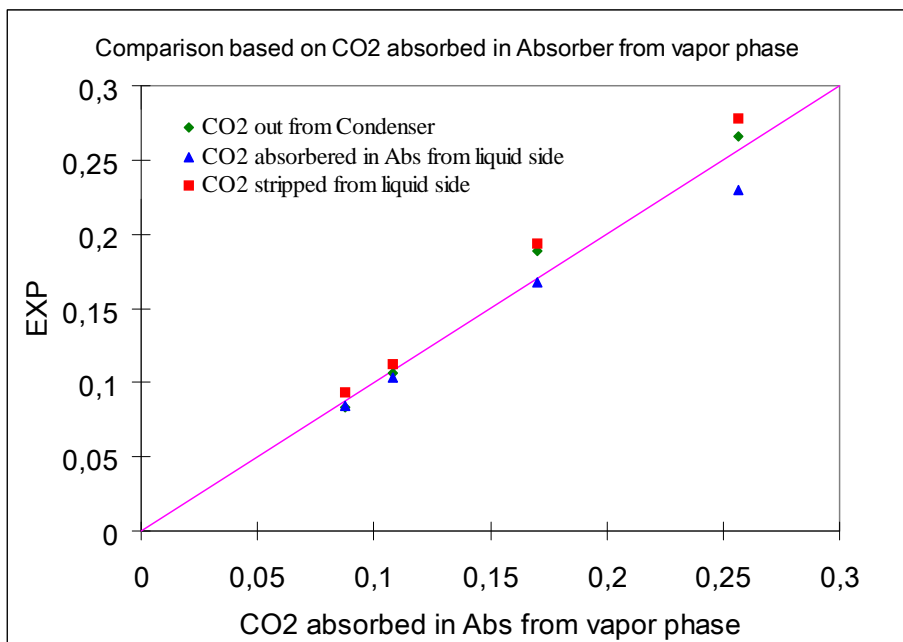
	1	2	3	4
20050302	0,102123	0,100868	0,099157	0,10458
20050311	0,109572	0,141429	0,101978	0,11467
20050312(1)	0,098825	0,10376	0,093087	0,09916
20050312(2)	0,115179	0,1397	0,112381	0,12308
20050314(1)	0,107977	0,106031	0,103661	0,112691
20050314(2)	0,085548	0,107367	0,079881	0,088867
20050316(1)	0,087681	0,08284	0,084559	0,09375
20050316(2)	0,169909	0,188687	0,167642	0,194015
20050401	0,090437	0,08939	0,08607	0,096631
20050404	0,109774	0,137967	0,114637	0,137919
20050405	0,256513	0,265828	0,229571	0,278261
20050406(1)	0,172046	0,207715	0,148461	0,196322
20050406(2)	0,131183	0,168057	0,129896	0,147714



Example: SINTEF/NTNU pilot

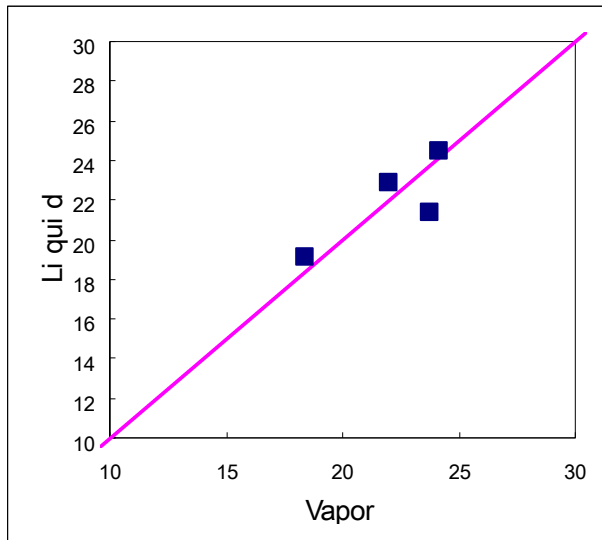
Selected runs:

Averaged liquid and gas phase values respectively

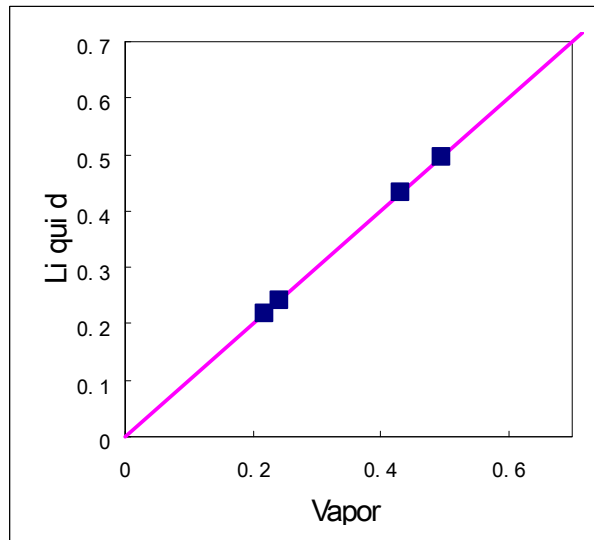


Run	Reb. Duty kW	T reb. C	Lean load	Rich load	% CO ₂ in	Liquid flow m ³ /h
14/03	9.6	119.5	0.217	0.333	2.45	0.18
16/03(1)	5.8	116.2	0.307	0.401	2.64	0.18
16/03(2)	11.6	117.1	0.297	0.390	5.32	0.36
05/04	13.4	116.0	0.346	0.429	9.48	0.54

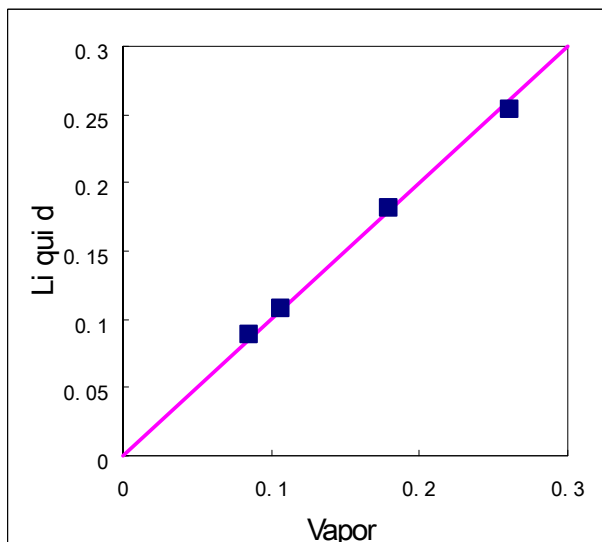
Experimental mass balances for all runs



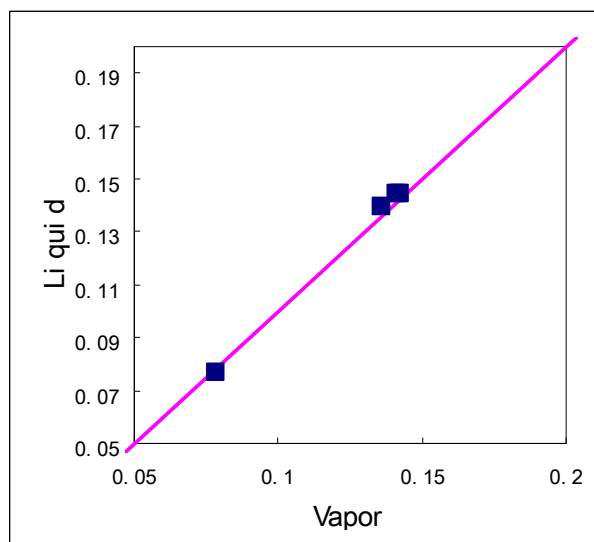
(a)



(b)



(c)



(d)

Mass transfer balances:

Average liquid phase in absorber and desorber

against

Average gas phase absorber and CO₂ product

Units: Kmol/h

- a) Dong Energy
- b) UoR, ITC
- c) NTNU/SINTEF
- d) ITT Stuttgart

Simulators tested

Commercial:

Aspen Plus, v2006.5 Radfrac, Vattenfall

Aspen Plus Rate Sep. (modified), IFP

ProTreat, NTNU

ProMax, University of Regina ITC

In-house

CHEMASIM (BASF SE), University of Kaiserslautern

CO2SIM, NTNU/SINTEF

Common basis for simulations

Rate based solvers:

- Design of physical plant

Experimental values:

- Inlet gas phase flow rate, composition and condition
- Absorber lean amine flow rate and amine concentration
- Absorber bottom and desorber reboiler pressures
- Lean amine loading at reboiler outlet
- Temperature approach for lean in/rich out in cross-flow HX

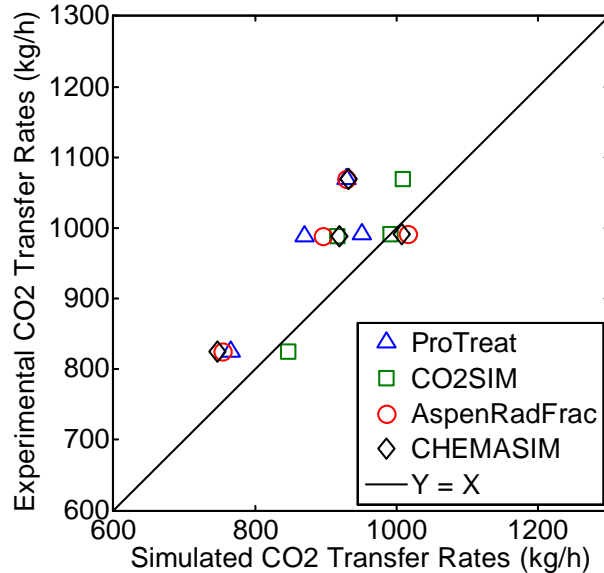
Aspen Rad Frac.

- Tuned to one test for each of the four pilot plants

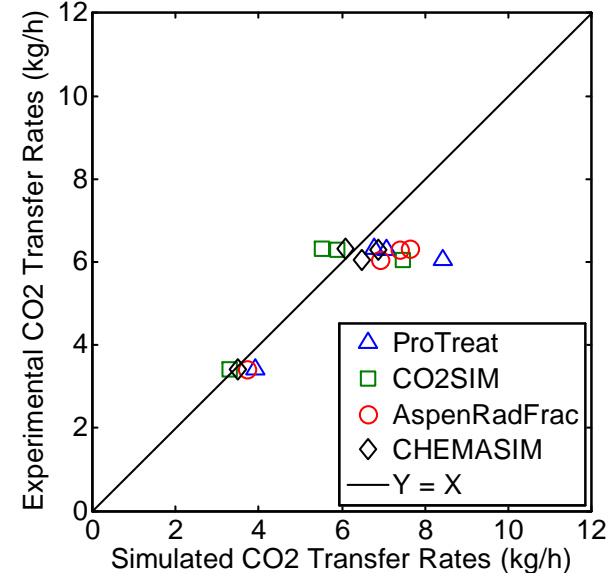
Comparative results for the simulators

Mass transfer rates

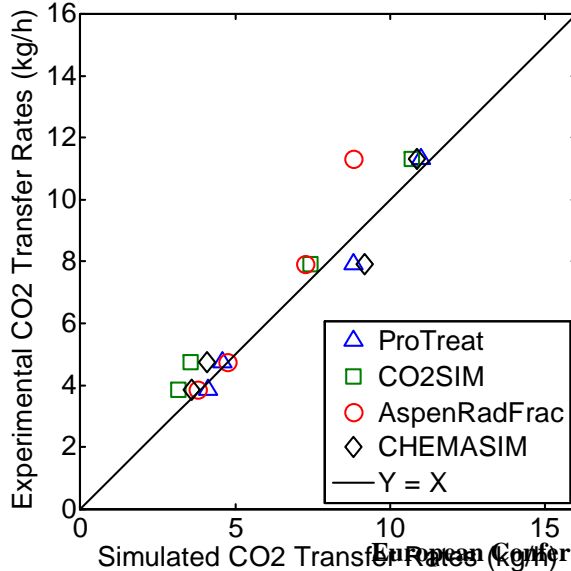
Experimental and Simulated CO2 Transfer Rates (DONG)



Experimental and Simulated CO2 Transfer Rates (ITT)



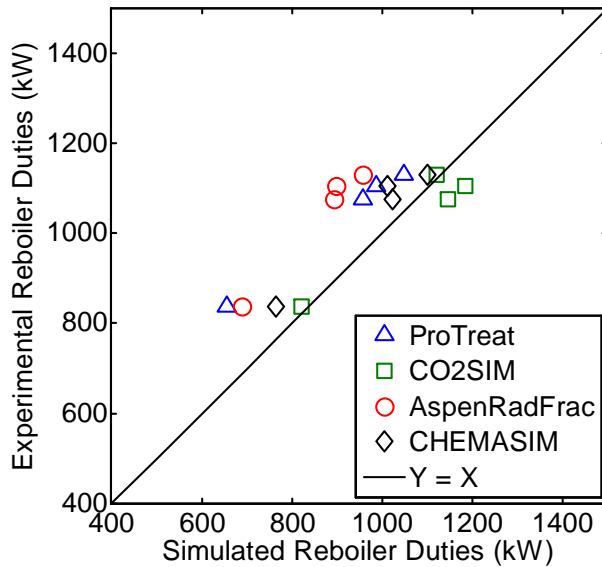
Experimental and Simulated CO2 Transfer Rates (NTNU)



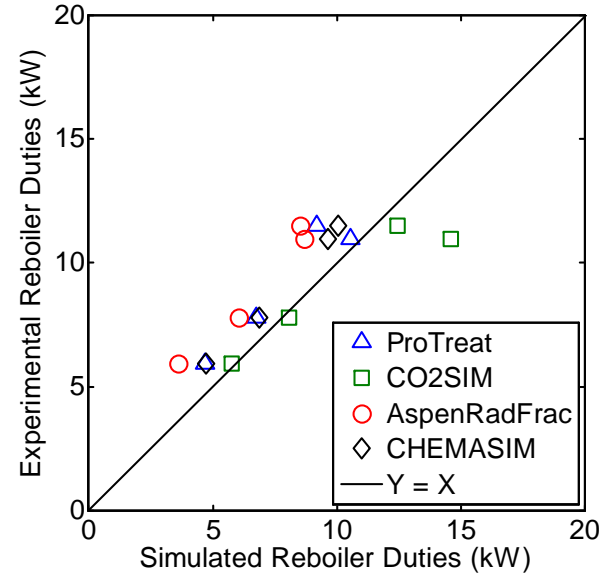
Mass transfer rates predicted generally within $\pm 15\%$, but deviations of nearly 30% occur

Reboiler duty

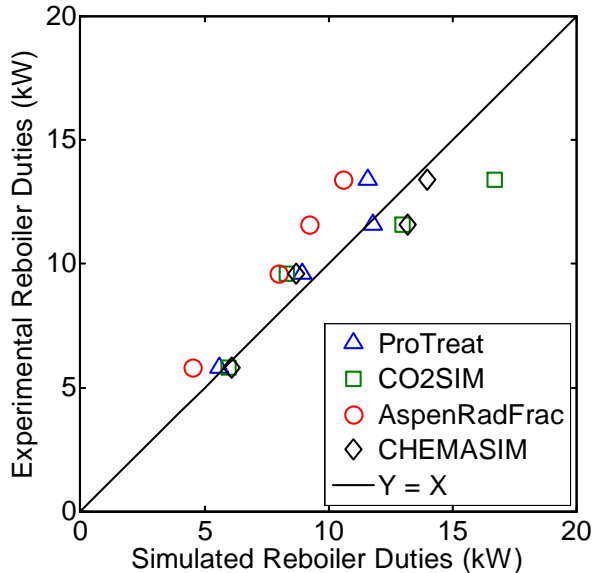
Experimental and Simulated Reboiler Duties (DONG)



Experimental and Simulated Reboiler Duties (ITT)



Experimental and Simulated Reboiler Duties (NTNU)



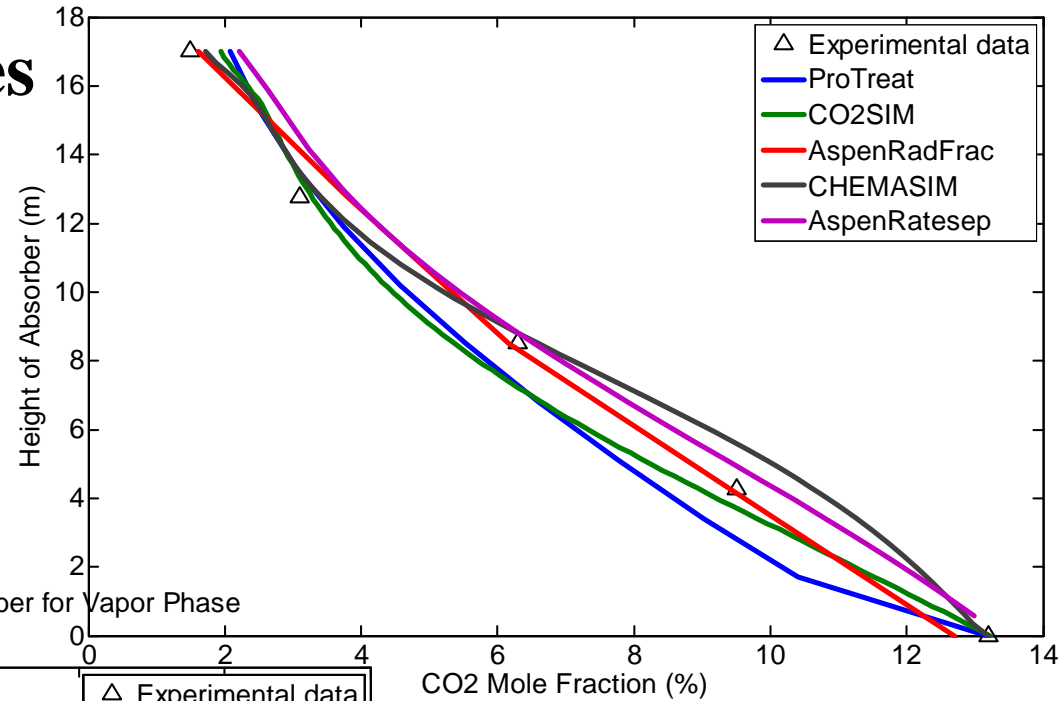
Heat duties predicted generally within $\pm 20\%$, but deviations of nearly 30% occur.

Experimental data have lower accuracy than for mass transfer

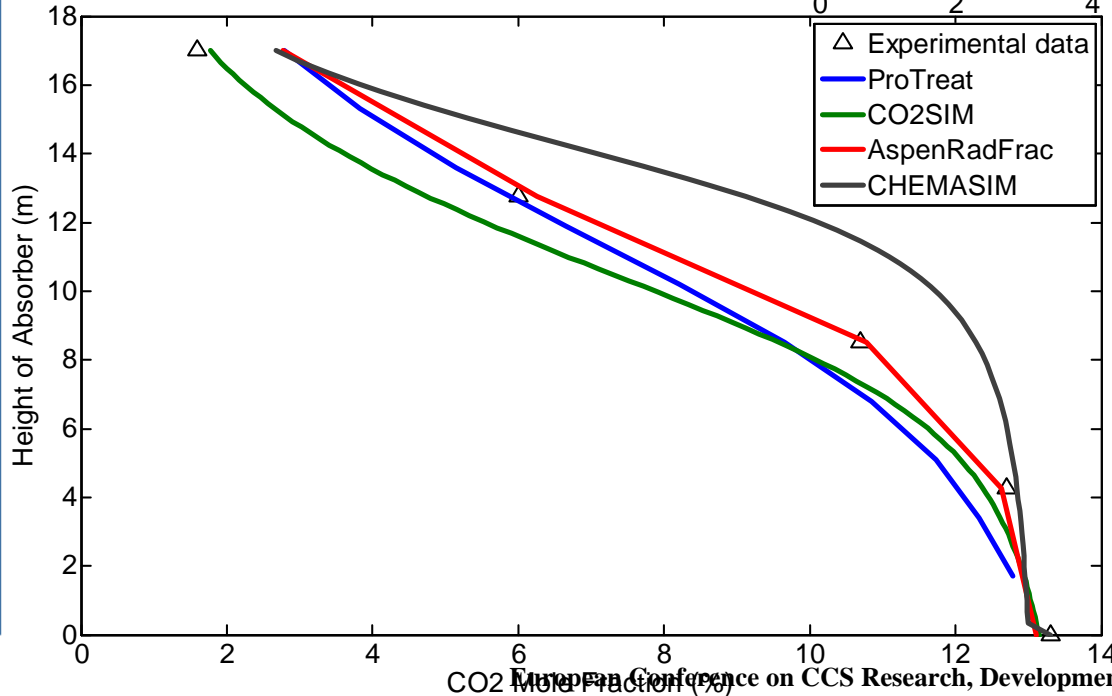
Gas phase CO₂ profiles

Data from DONG

Simulated Concentration Profiles in Absorber for Vapor Phase (DONG Test1A)



Simulated Concentration Profiles in Absorber for Vapor Phase (DONG Test1E)

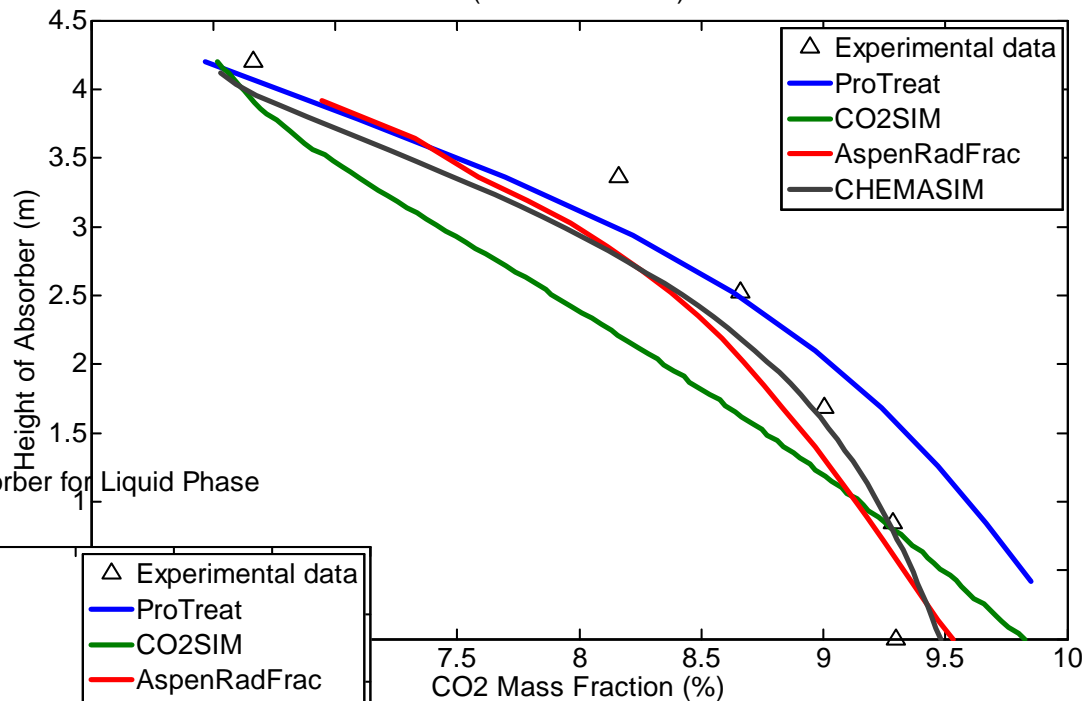


Aspen Rad Frac fitted to experimental points

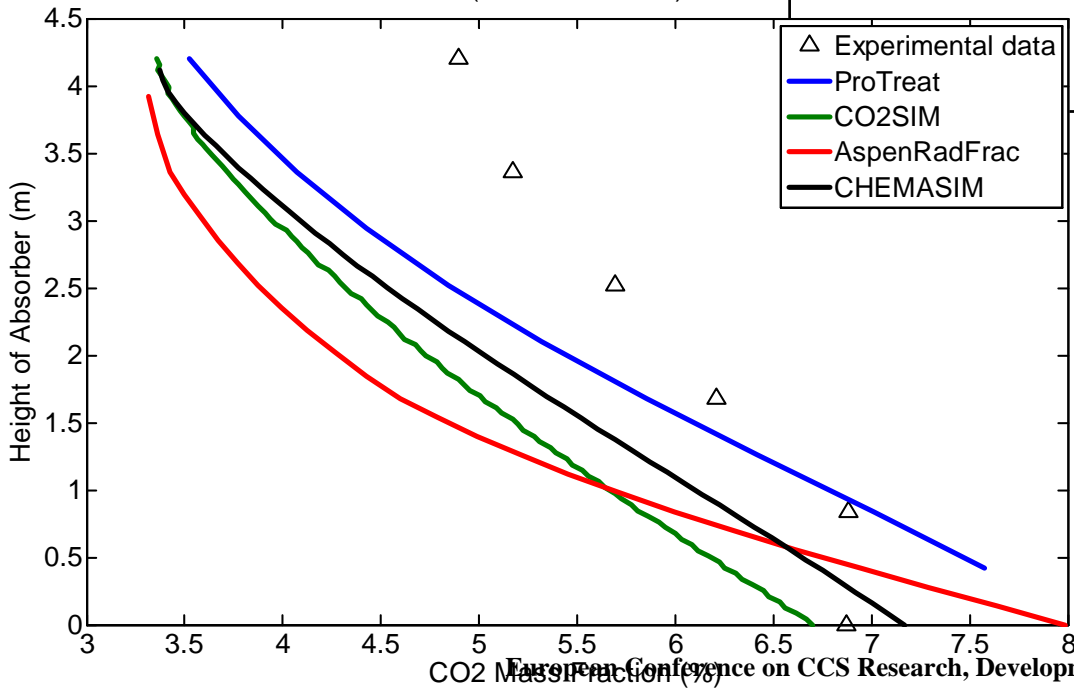
Liquid phase CO₂ Profiles, absorber

Data from ITT

Simulated Concentration Profiles in Absorber for LiquidPhase (ITT 20070604-1)



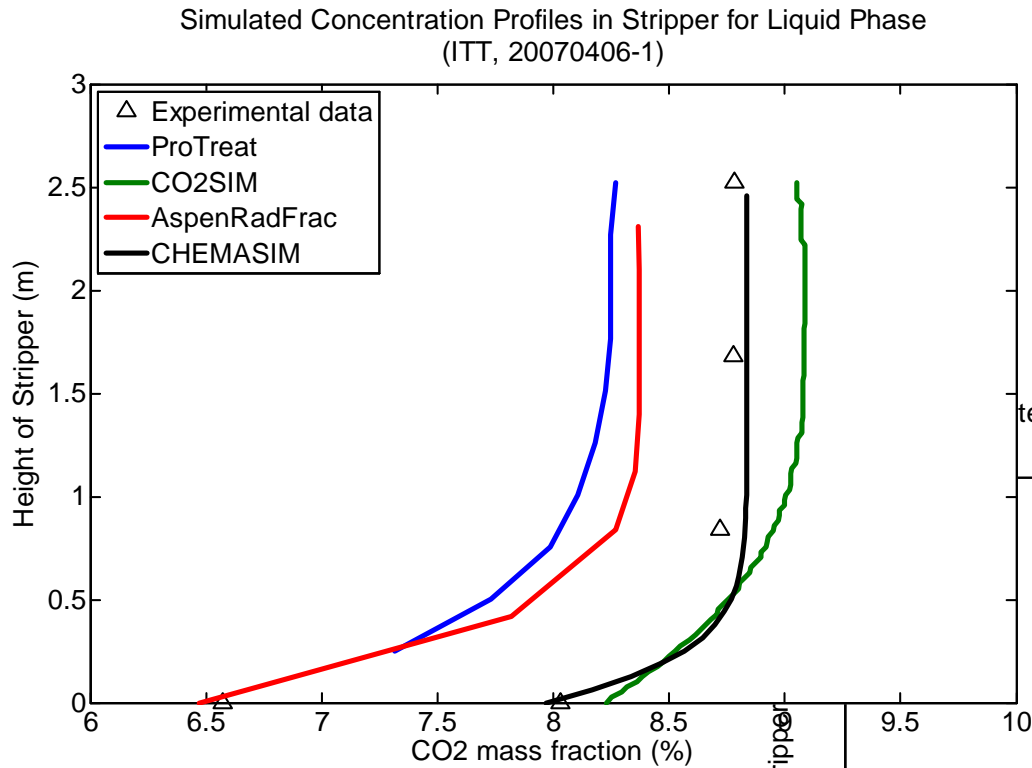
Simulated Concentration Profiles in Absorber for Liquid Phase (ITT 20070618-2)



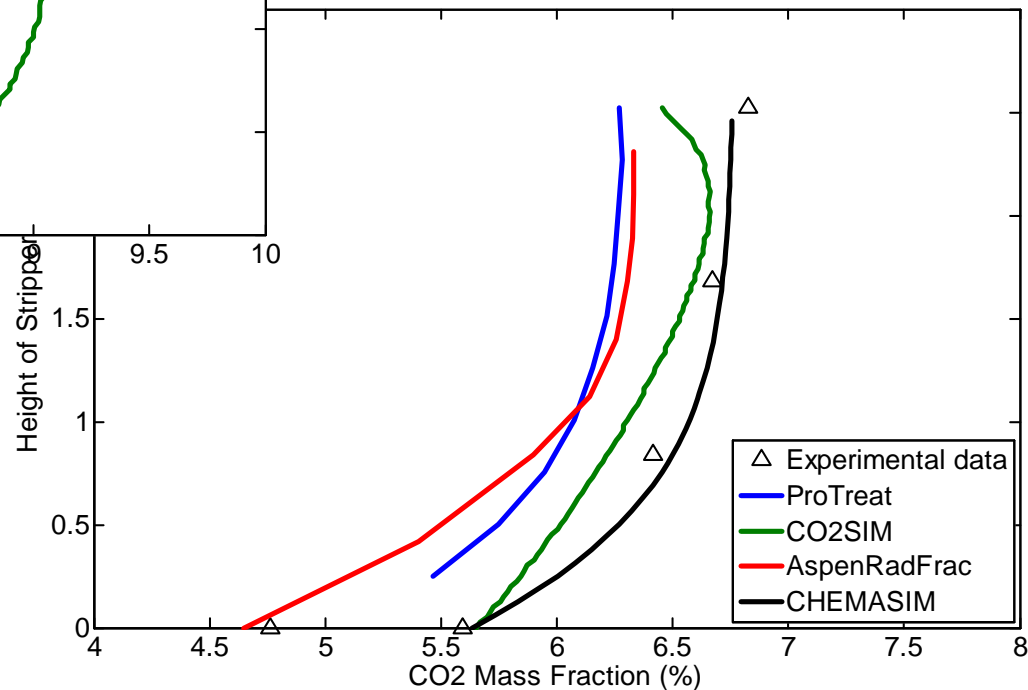
Aspen Rad Frac not fitted to experimental points

Liquid phase CO₂ profiles, desorber

Data from ITT



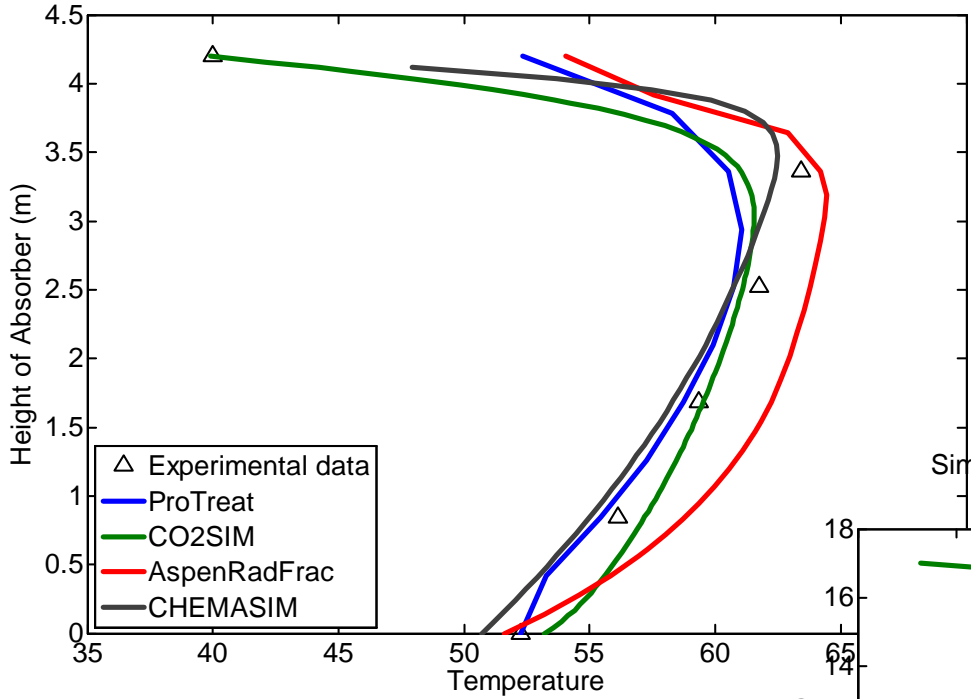
Simulated Concentration Profiles in Stripper for Liquid Phase
(ITT, 20070611-1)



Aspen Rad Frac not fitted to experimental points

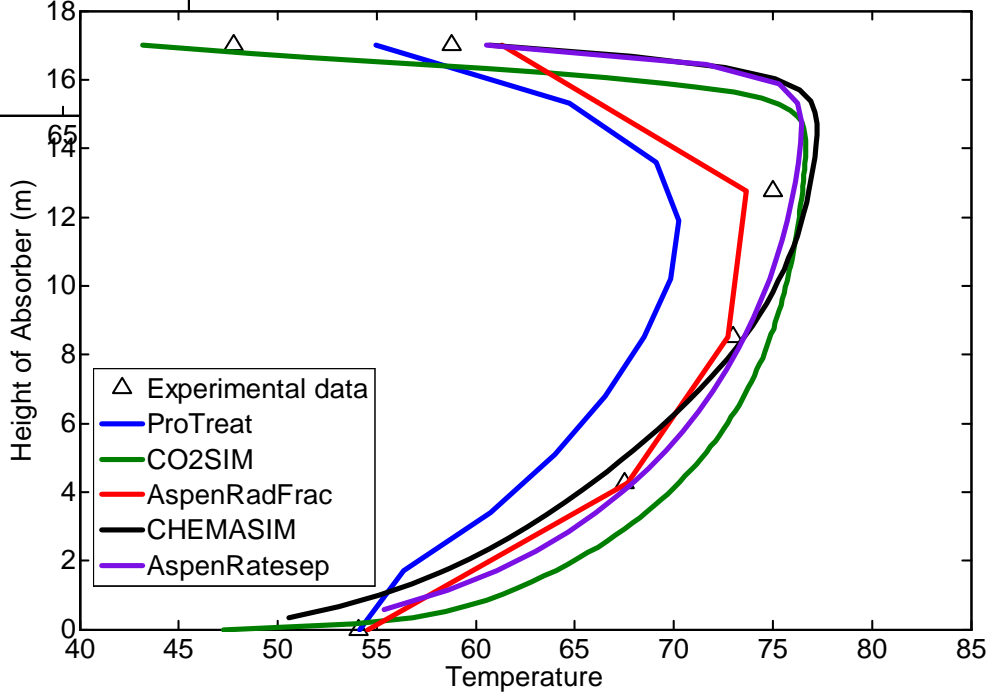
Temperature profiles, absorber

Simulated Temperature Profiles in Absorber for Liquid Phase
(ITT 20070618-2)



Liquid phase ITT

Simulated Temperature Profiles in Absorber for Vapor Phase
(DONG Test1A)

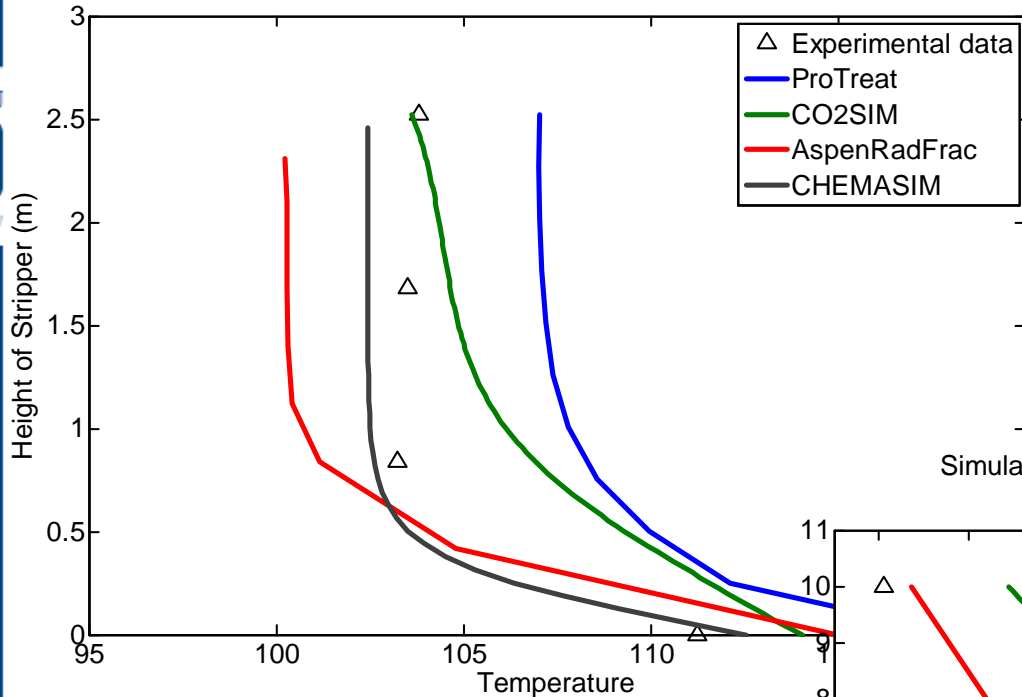


Gas phase DONG



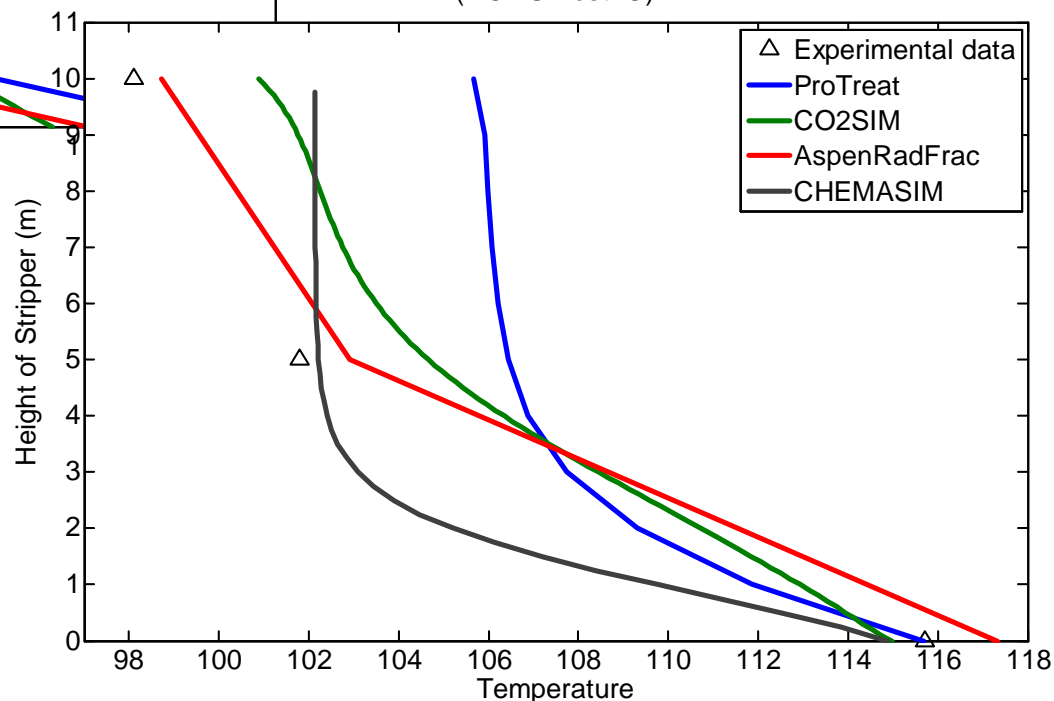
Temperature profiles, desorber

Simulated Temperature Profiles in Stripper for Liquid Phase
(ITT 20070604-1)



Liquid phase ITT

Simulated Temperature Profiles in Stripper for Liquid Phase
(DONG Test2C)



Gas phase DONG



Summary

Six different simulators have been tested on 16 sets of data from four different pilot plants

- Mass transfer predicted within $\pm 15\%$
- Reboiler heat duty predicted within 20%
- Predictions of gas phase concentration profiles vary significantly
- Predictions of liquid phase absorber and desorber conc. profiles vary greatly
- Predictions of liquid phase desorber conc. profiles vary greatly
- Predictions of absorber temperature profiles within $\pm 2-3^{\circ}\text{C}$
- Predictions of desorber temperature profiles within $\pm 4-5^{\circ}\text{C}$

Rate based simulators performed with approximately same accuracy

No correlation between pilot size and simulation agreement

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Are we satisfied with this???

Acknowledgement

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