


TNO innovation for life

CLEO
Carbon Lean Energy Operation

AMP/PZ emissions

Maasvlakte pilot plant measurements and modelling

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  - Measurement campaign: corrosion, performance, emissions
  - Pilot configuration and measurement set-up
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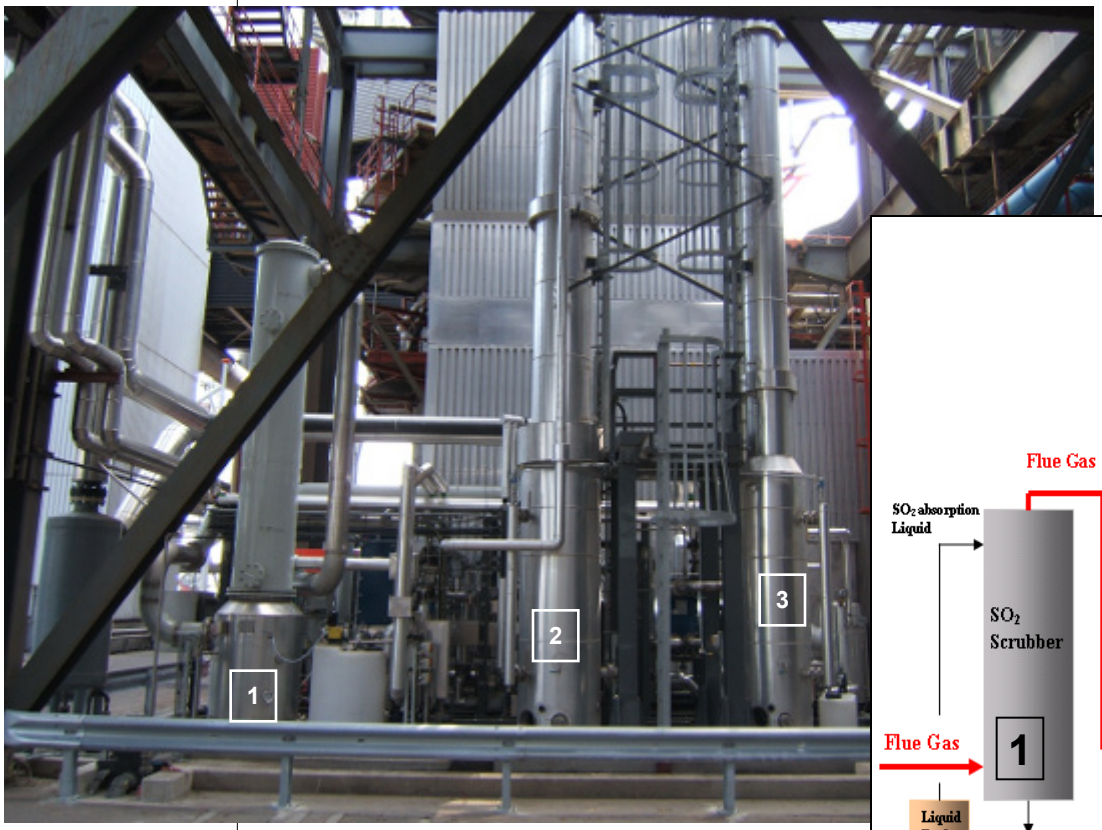
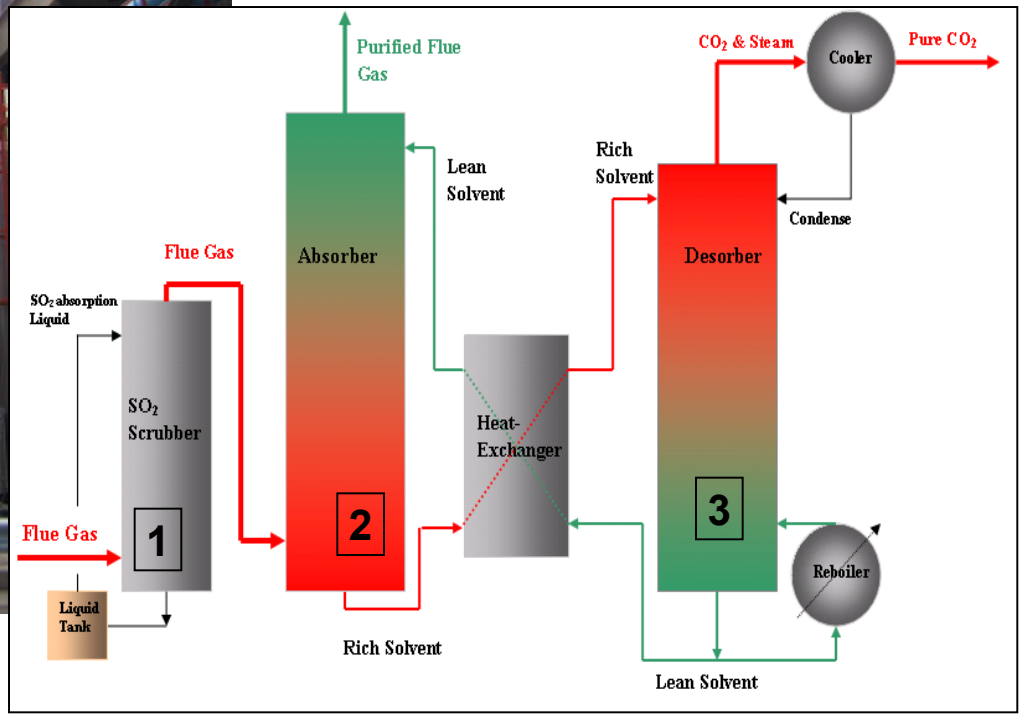
  - Comparison with literature
  - Comparison with pilot plant
  - Modelling of a double washing section

Pilot plant measurement set-up





Pilot plant measurement set-up

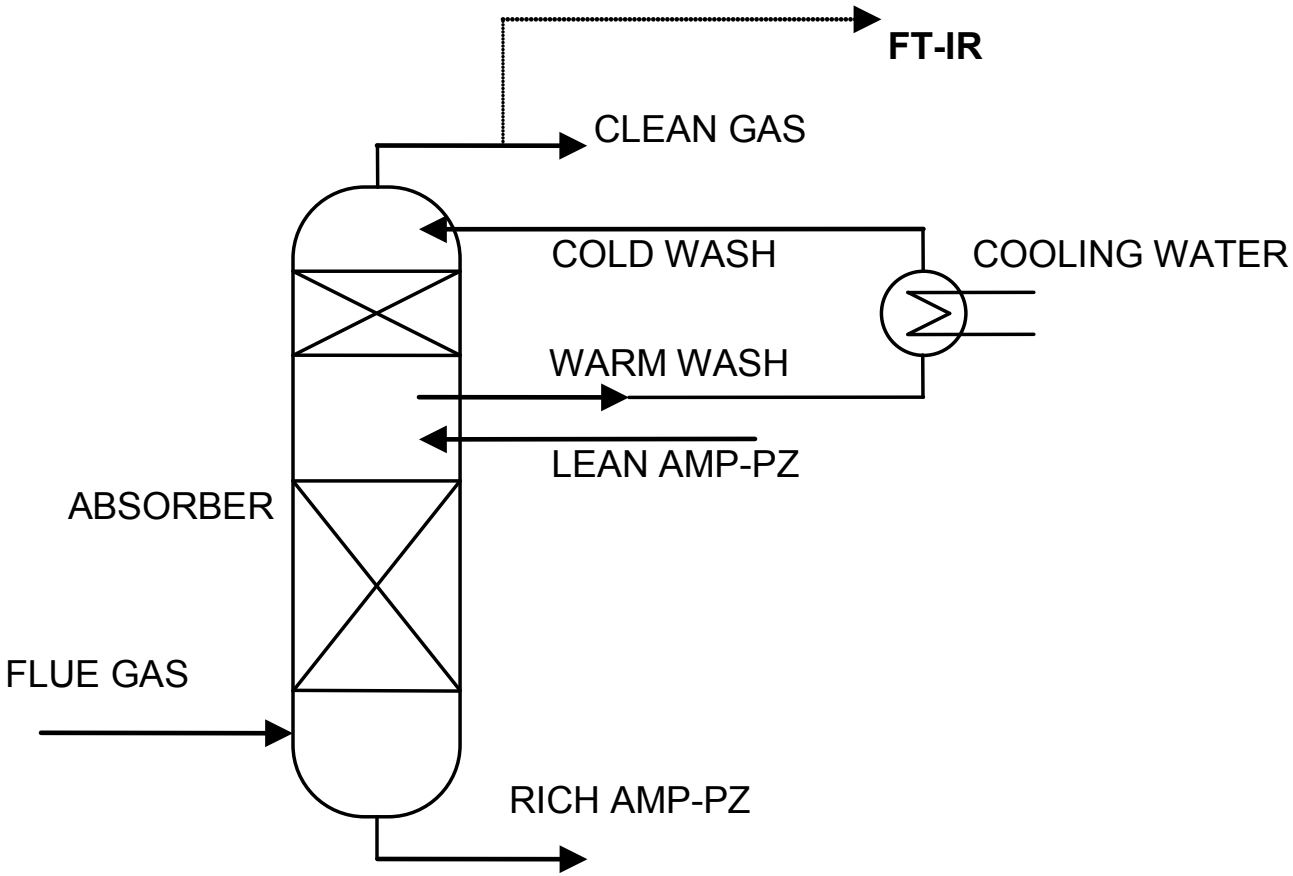
Flue gas details:
Connected to coal fired power plant
1250 m^3/h flue-gas (@ 12% CO_2)
250 kg/h CO_2 capture
90% of CO2 capture

Absorber:
8 m height
Dumped Packing: IMTP 50
Diameter: 650 mm

Wash section:
2 m height
Dumped Packing: IMTP 50
Cooled water recycle over bed

Pilot plant measurement set-up

- FT-IR (Laborelec) connected to clean gas exhaust of the pilot.



Settings

- Operation near 90% capture
- Variation of absorber temperature and wash water flow
- Settings used:

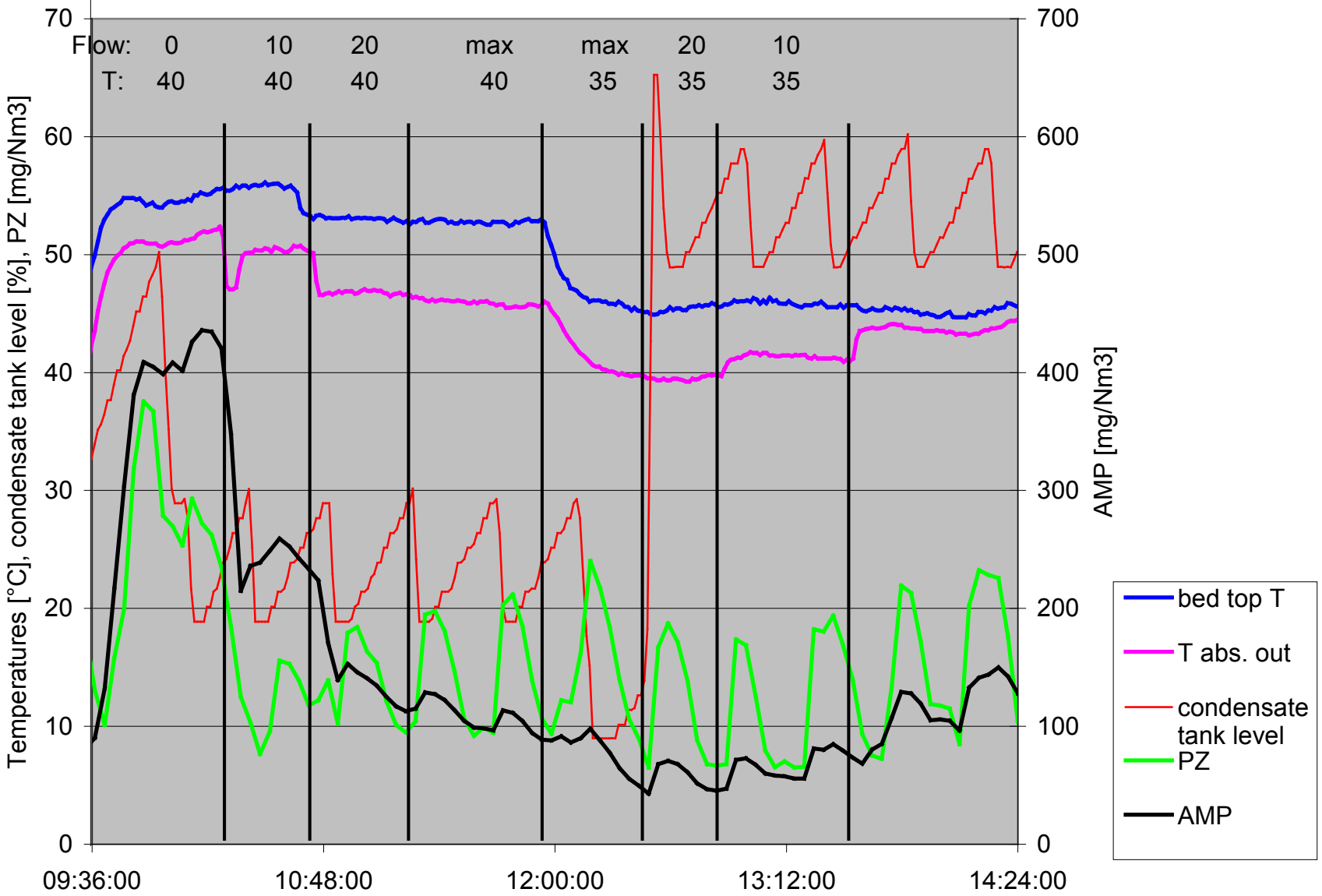
Wash flow	l/min.	0	10	20	max	max	20	10	0	0	10	20	max
Lean T	°C	40	40	40	40	35	35	35	35	45	45	45	45

- Each setting maintained for 30-50 minutes

Pilot plant measurement set-up

- Measurement conditions:
  - Environmental permitting delayed until winter:
    - Demi water etc. frozen in periods of frost

Results: accuracy of readings



Results

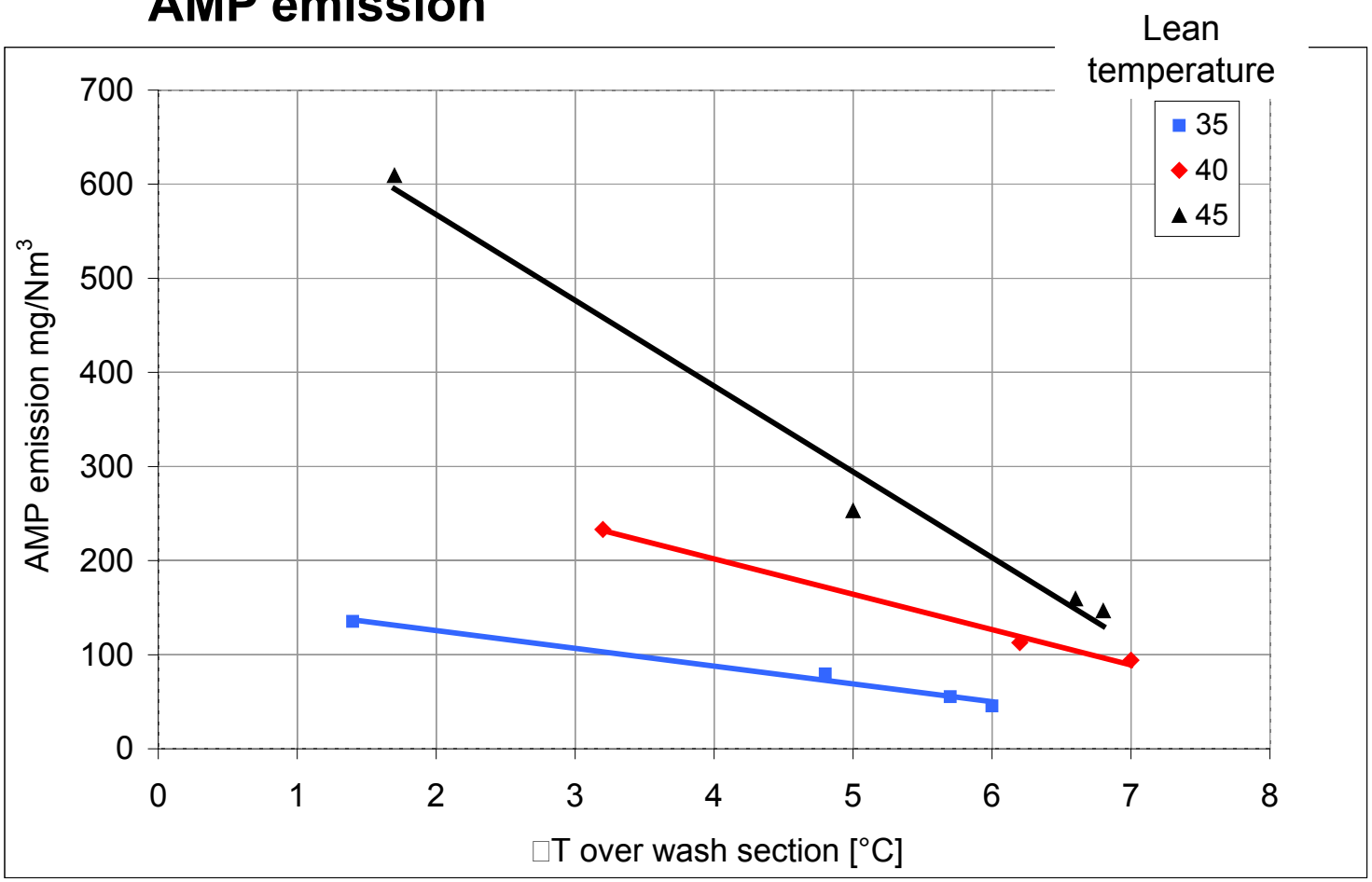
- Process trends

(more results in modelling section)

T_{lean} AMP-PZ	°C	40	40	40	35	45
Wash flow	l/min.	10	20	max	20	20
T abs. gas out	°C	50.2	46.6	46.0	39.8	50.7
T top abs. bed	°C	53.4	52.8	53.0	45.8	57.3
T wash-liq. in	°C	29	38	39	34	40
H_2O	vol%	11.7	9.9	9.4	6.9	11.8
AMP	mg/Nm^3	233	113	94	45	159
PZ	mg/Nm^3	12	14	15	7	7
Capture percentage		92	89	88	88	89

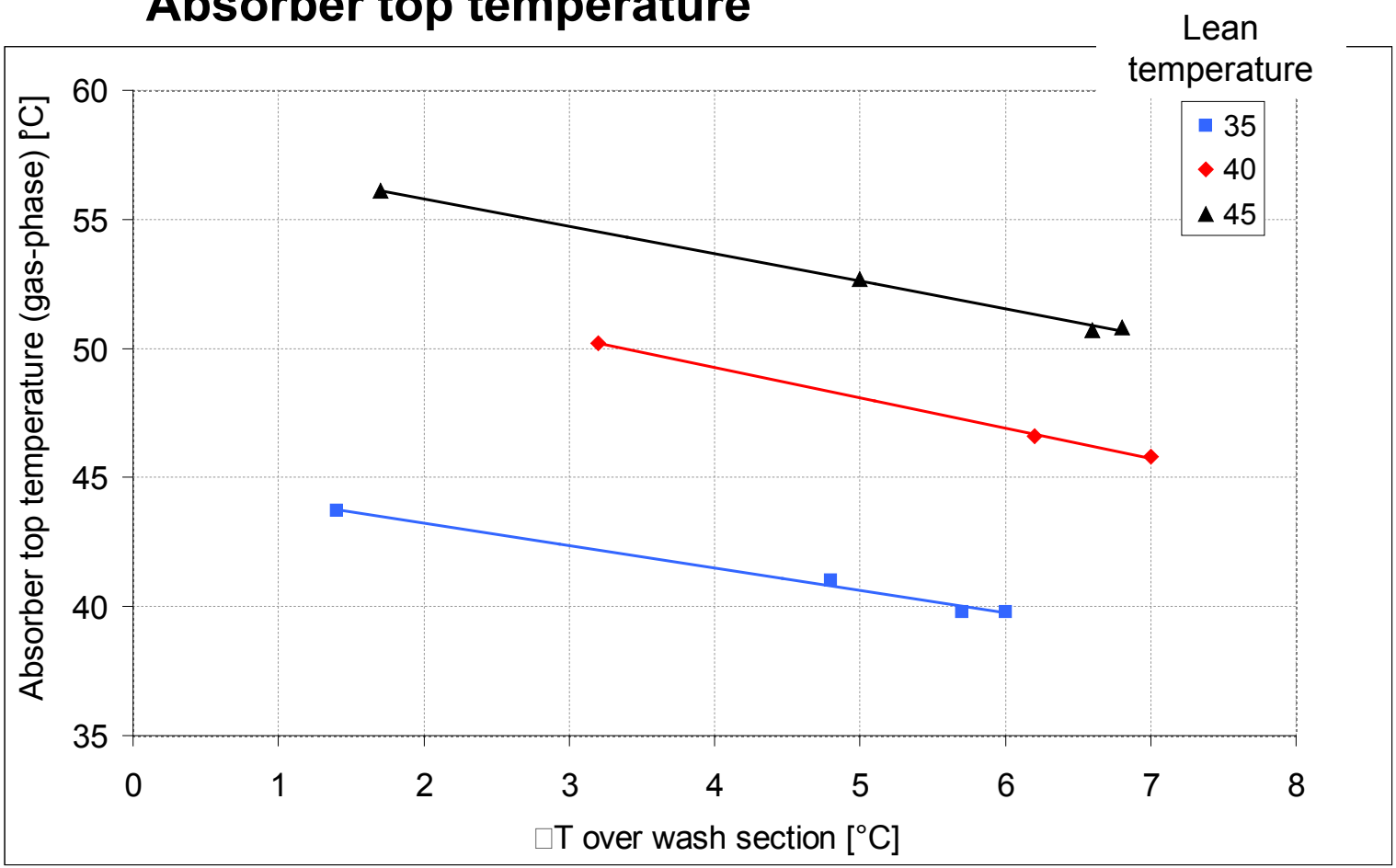
Results: AMP trends

AMP emission



Results: AMP trends

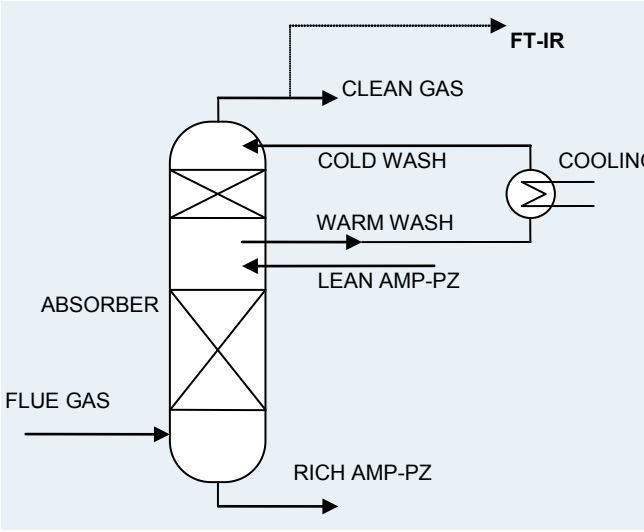
Absorber top temperature



Aspen Plus modelling

- Starting point: merged, unaltered AMP-PZ model (Aspen Plus)
- Comparison pure component vapour pressures with literature: exact match
- Model structure
- Comparison with pilot

Aspen modelling: model set-up



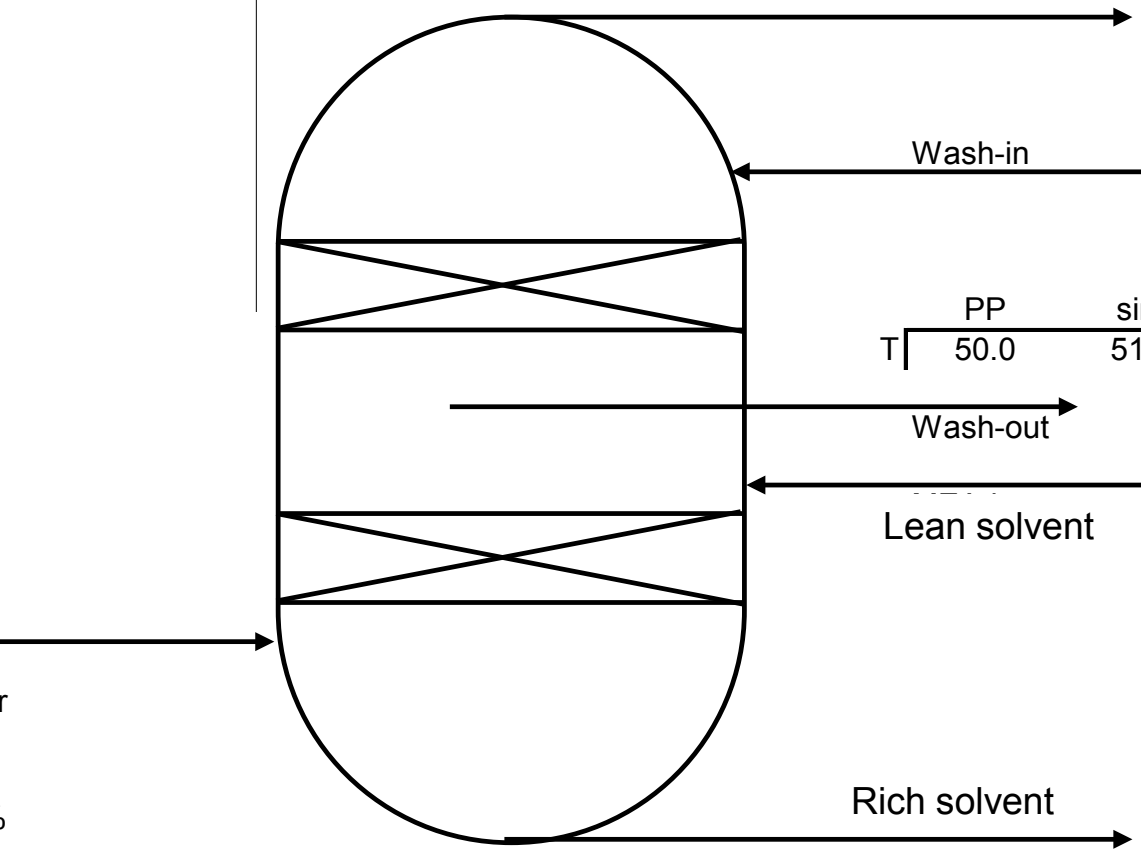
- Only absorber and wash section modelled
- Wash section: 2 equilibrium stages
- Absorption: 3 stages at 70% of equilibrium: ~90% capture
- Emissions very temperature dependent:
  absorber top temperature and Cleangas out temperature are input
  (solvent flow and wash flow used to attain T's)
- All parameters of column input streams are input data to simulation
  (except for solvent and wash flows)

Aspen modelling

- Results one setting:

~25 l/min wash, lean T: 40°C

	PP	sim	
T	46.0	46.0	°C
P			bara
AMP	94	102	mg/Nm3
PZ	14	8	mg/Nm3
H2O	9.4	10.0%	vol%
CO2	1.45%	1.4%	vol%



	PP	sim	
Flow	>20	26.4	l/min
T	38.0	38.0	°C
CO2		0.28	M
AMP	0.61	0.68	M
PZ	x	0.16	M

	PP	sim	
T	50.0	51.7	°C

	PP	sim	
Flow	4	3.5	ton/h
T	40	40	°C
CO2	0.59	0.59	M
AMP	3.1	3.1	M
PZ	1.2	1.2	M

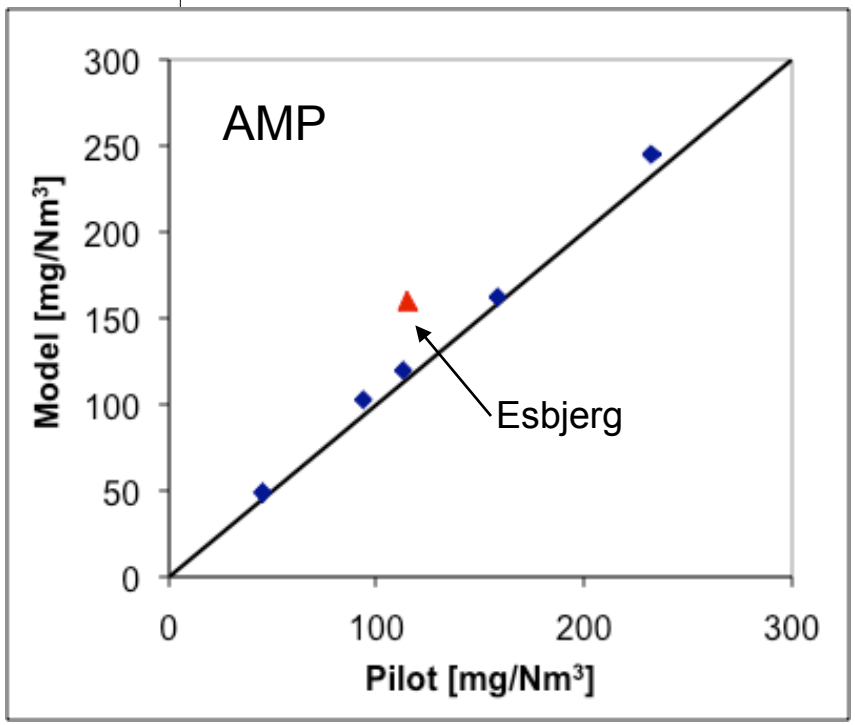
Aspen modelling

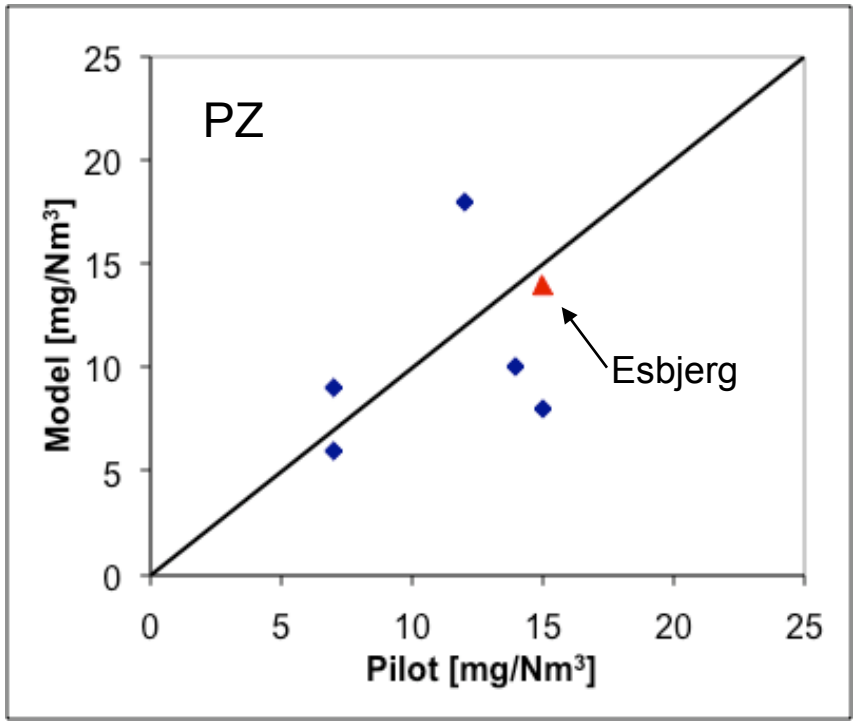
- **Results at 40°C lean temperature** (blue numbers: model)
  - Capture trend OK
  - Calculated wash- and lean solvent flows near to pilot readings
  - Absolute value AMP emission close to Aspen readings
  - The AMP results of model and pilot being close **indicates** that no significant entrainment has occurred.

T(lean)	°C	40	40	40	40	40	40
Wash flow	l/min	10	8.4	20	24.2	max	26.4
AMP	mg/Nm3	233	273	113	119	94	102
PZ	mg/Nm3	12	22	14	10	15	8
H20	vol%	11.7	12.2	9.9	10.3	9.4	10
Capture %		92%	90%	89%	90%	88%	90%
Tg Abs, out	°C	50.2	50.2	46.6	46.6	46.0	46.0
Tg wash out	°C	53.4	53.9	52.8	53.1	53.0	53.1

Aspen modelling

- **Results summary**: parity plots
  - Good fit AMP results
  - PZ: range is OK





Aspen modelling

Results for a double washing section

- Washing sections do not work if they are not cooled or fed with clean water
- Very high AMP and PZ washing efficiency possible
- Wash flow and cooling duty very high: optimisation needed

  (extra benefit: closed water balance)

- Result for 800 MW ASC with capture plant:

section:		Absorption	lower wash	higher wash
T gas out	°C	60	47	35
T liquid in	°C	30	30	30
liquid feed flow	kg/s	1300	1000	1000
AMP	mg/Nm^3	3875	46	0.16
PZ	mg/Nm^3	298	1.4	0.00

General conclusions

- Operation **near** steady state due to short measurement times
- Some fluctuations in especially PZ emission, likely due to stripper operation.
- Fair washing efficiencies for AMP with different wash water flows
- Emission could be lowered further with more cooling
- Results Aspen simulation in fair agreement with pilot results
  - An **indication** that entrainment is very limited: further research needed
  - Aspen can be used to evaluate double wash section for AMP/PZ

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