PILOT PLANT RESULTS FOR 5 M PIPERAZINE WITH THE ADVANCED FLASH STRIPPER

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UT PZ Pilot Plant Testing

2008

8 m PZ
Absorber
Mellapak 2X
Simple Stripper

2010

8 m PZ
AbsIntercooling
RSP 250-hybrid
Simple Stripper
120 °C

2010/2011

8 m PZ
AbsIntercooling
RSP 250-hybrid
2-Stage Flash
150 °C, 12 bar

2011

8 m PZ
AbsIntercooling
GTC-350Z, 70°
2-Stage Flash w/
Warm Rich Bypass
150 °C, 14 bar

2013

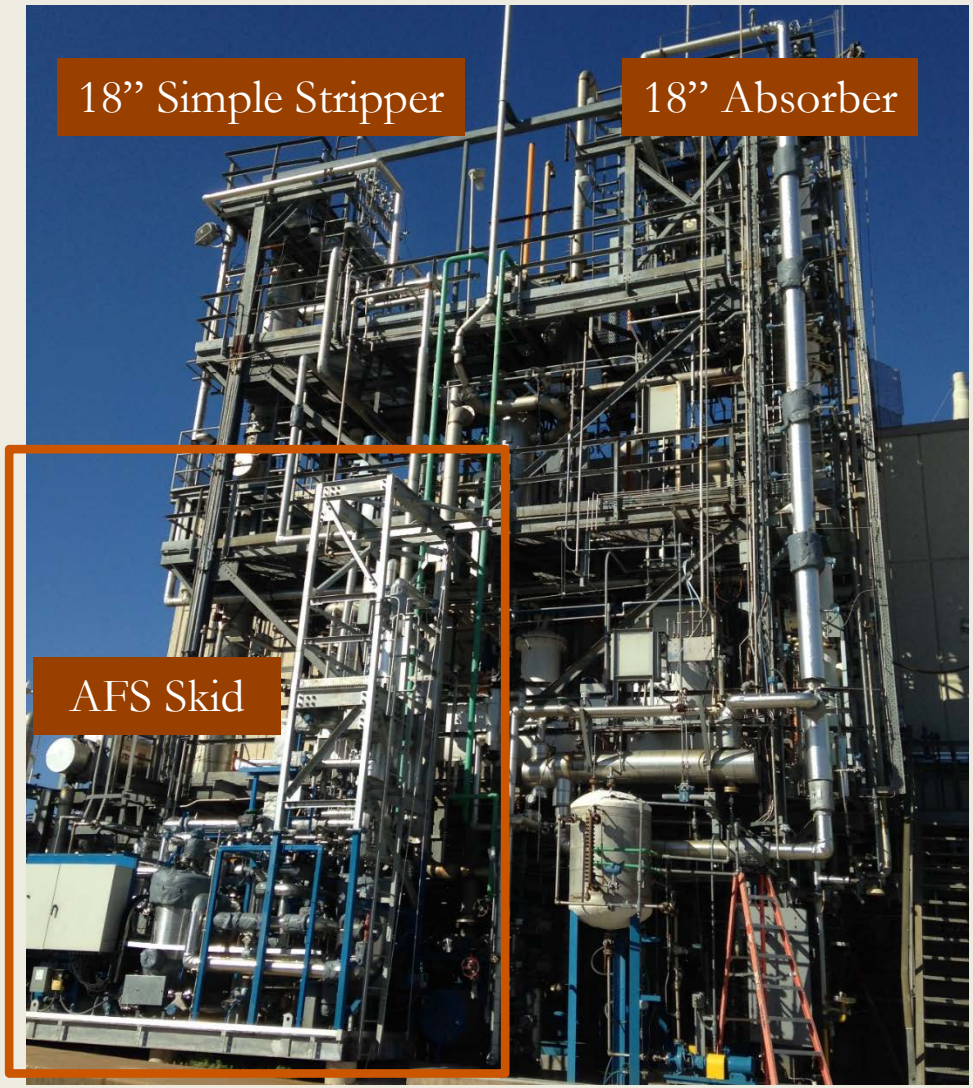
4 m PZ
AbsIntercooling
RSP-250
1-Stage Flash w/
Cold Rich Bypass
140 °C, 4.4 bar
Aerosols, G2 PDI

2015

5 & 8 m PZ
AbsIntercooling
RSP-250
Adv Flash Stripper
Cold/Warm Rich
Bypass, 150 °C, 8 bar
Aerosols, G3 PDI

Current Pilot Facilities & Equipment

- SRP - 0.1 MW, 16.8-inch ID
- 200-450 lb CO_2/hr removal)
- Synthetic Flue Gas: Air/CO_2
  - Enthalpy, 1-2 % H_2O, 30-40 °C
  - 3-20% inlet CO_2
  - Air max. oxidative degradation
- 20 feet (6.1 m) absorber packing
- Absorber intercooling
- 0.1-0.2 MW AFS skid w/cold and warm rich bypass



Concentrated PZ Benefits

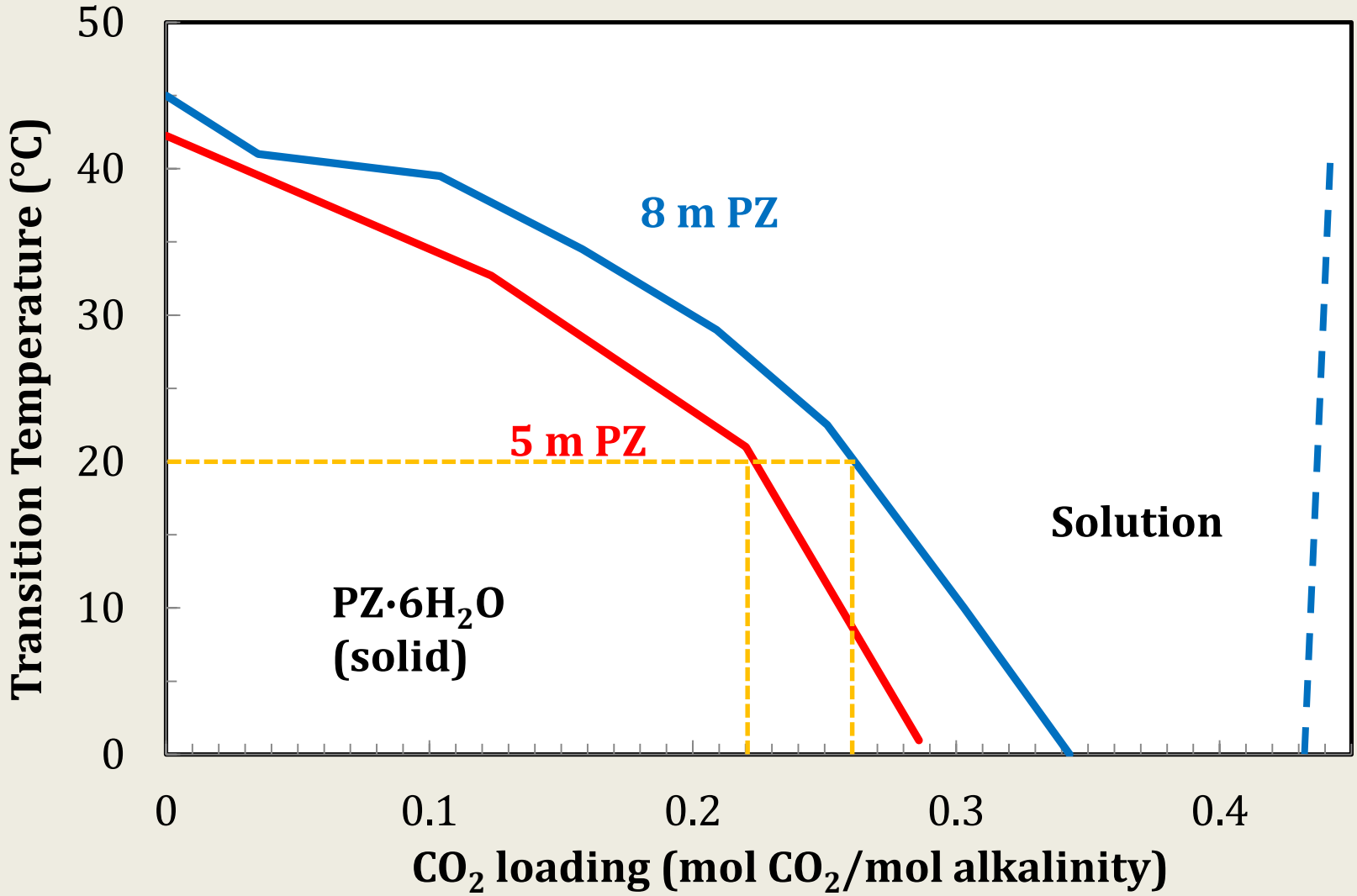
8 m PZ → 5 m PZ

Solvent	Rate[1]	CO_2 Capacity[2]	Viscosity[3] (cP)	T_{max} (°C)	P_{max} (bar)
5 m PZ	**11.3**	**0.63**	**3**	**163**	**14.3**
8 m PZ	8.5	0.79	10.8	163	14.3
7 m MEA	4.3	0.5	2.5	120	2.2

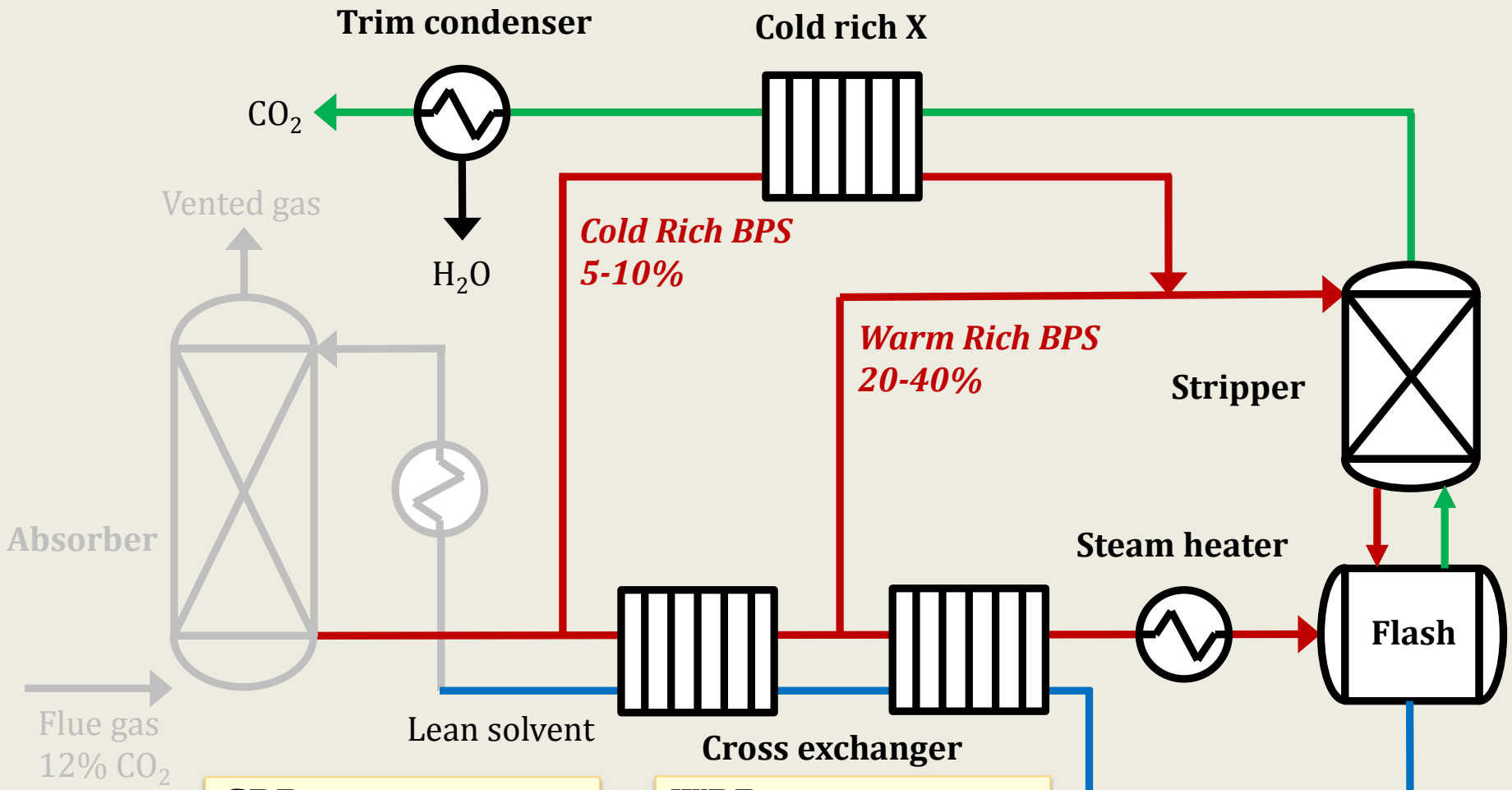
Notes:

1. k_g' average @ 40 °C – (mol/Pa-s-m^2)
2. mol CO_2/mol alkalinity
3. @ 40 °C

Solubility of 5 m PZ and 8 m PZ



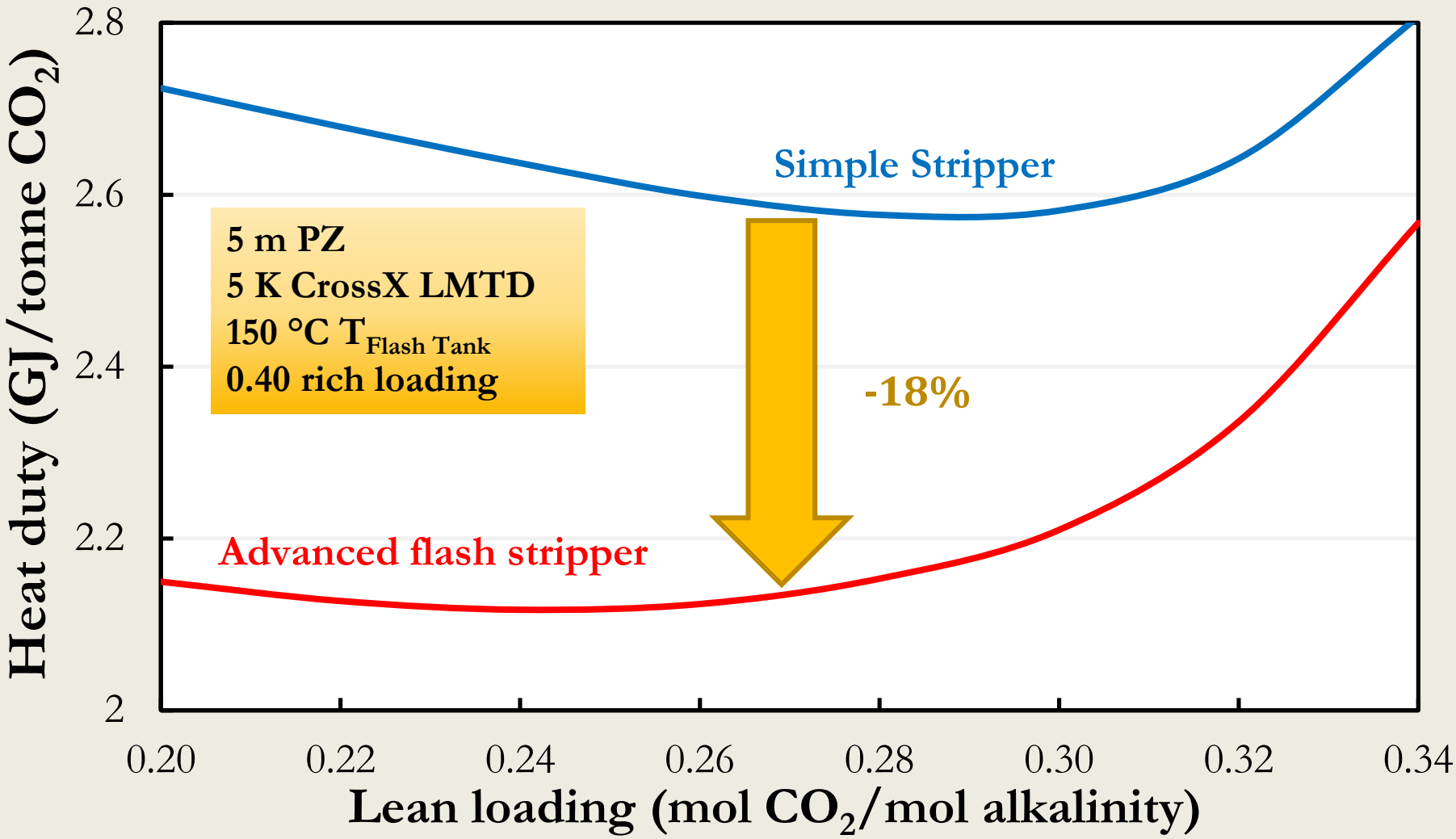
Advanced Flash Stripper Configuration



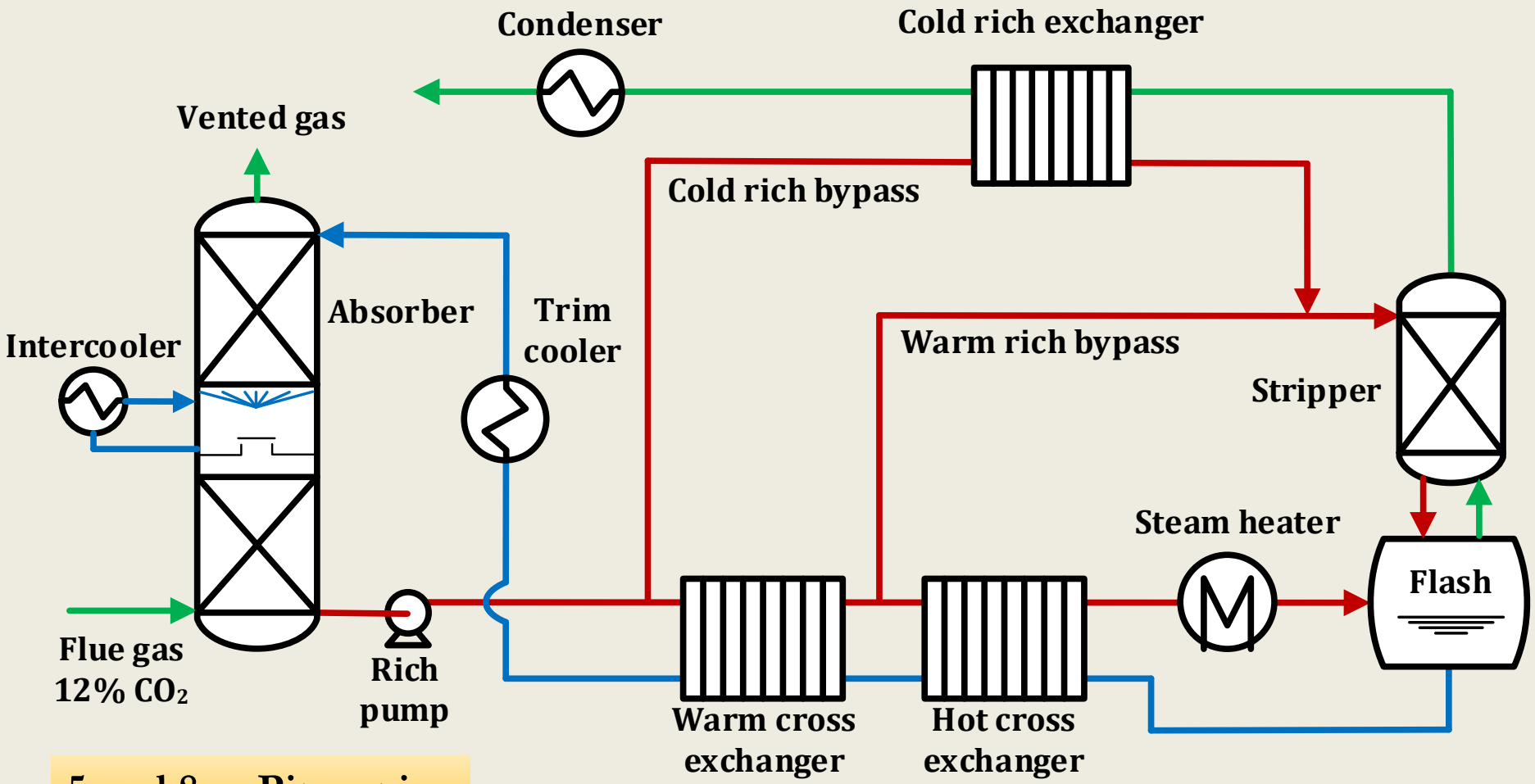
CRB:
- Recover heat gas
- Indirect contact

WRB:
- Non flashing feed
- Optimal L/G

Adv. Flash Stripper Energy Performance

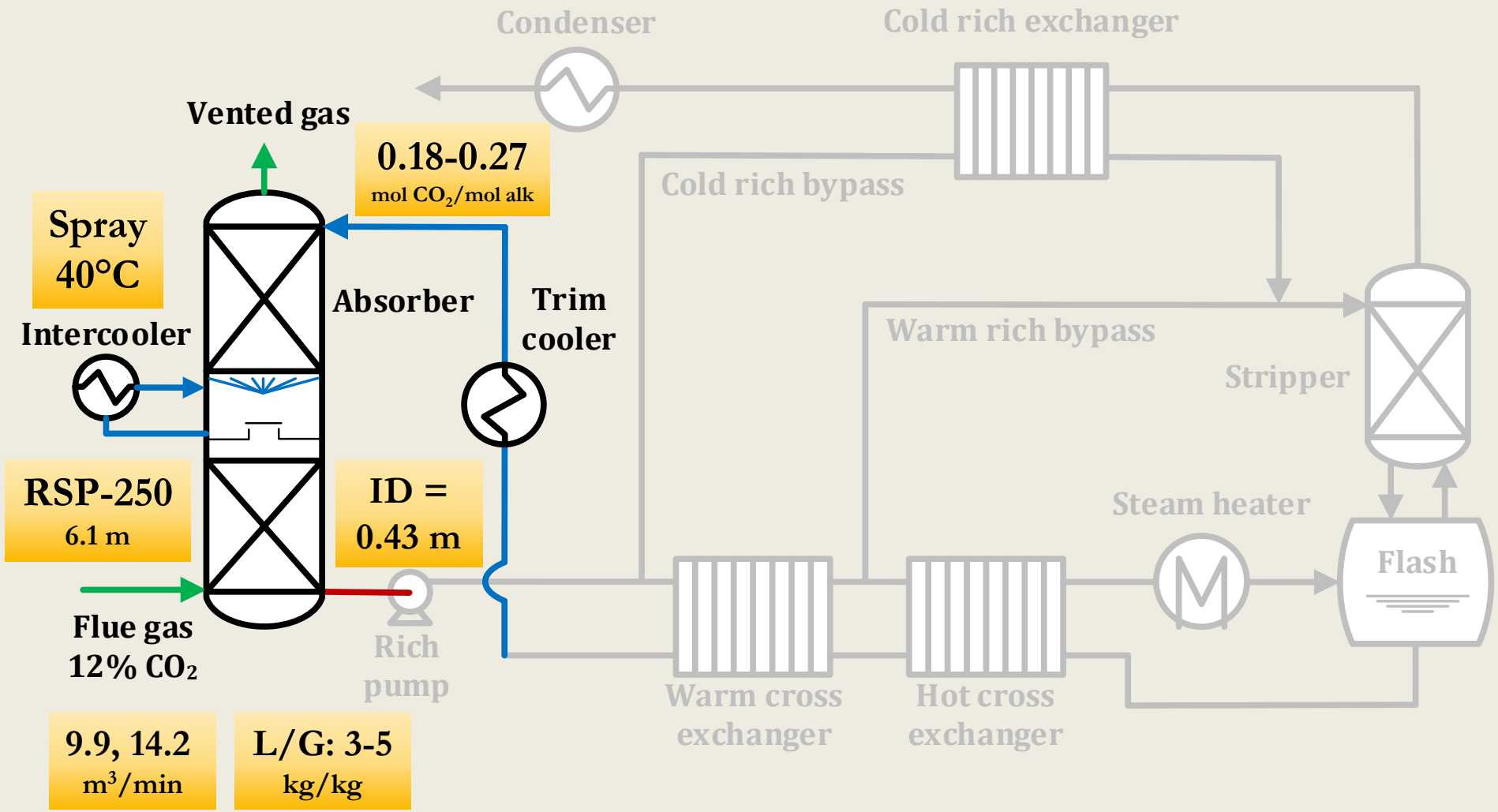


2015 AFS Campaign Configuration

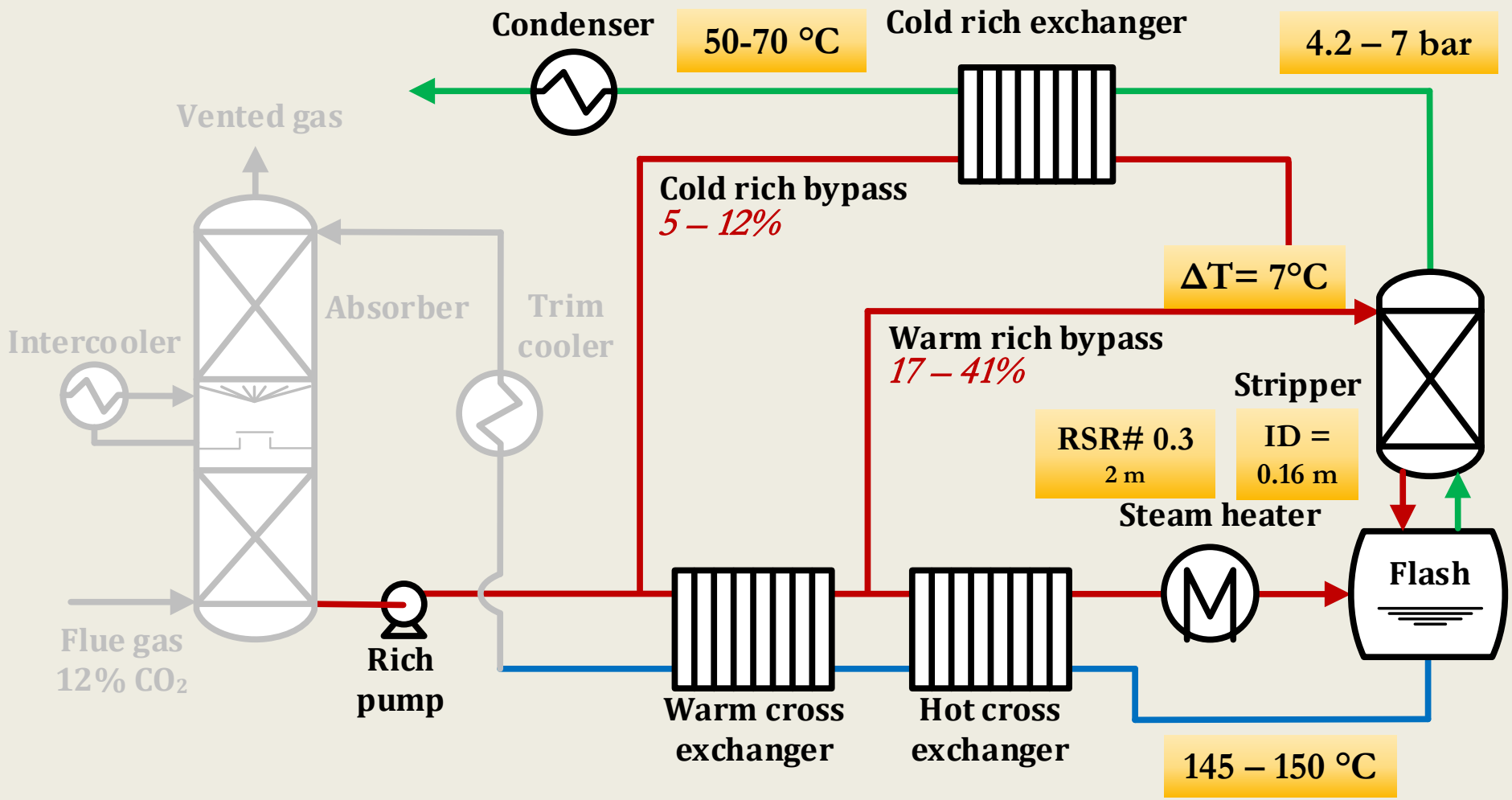


5 and 8 m Piperazine

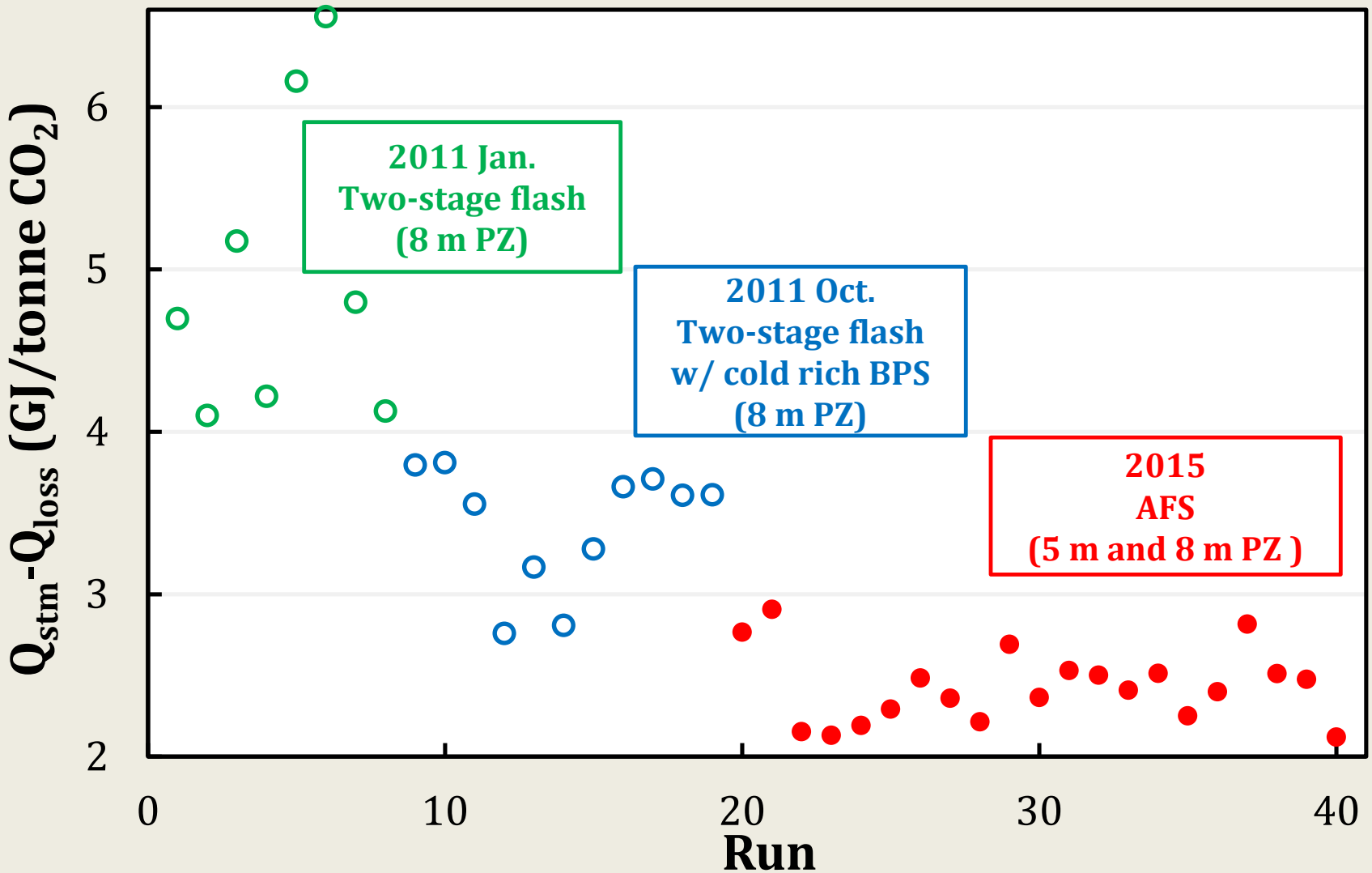
Absorber Conditions



Stripper Conditions



AFS Energy Performance

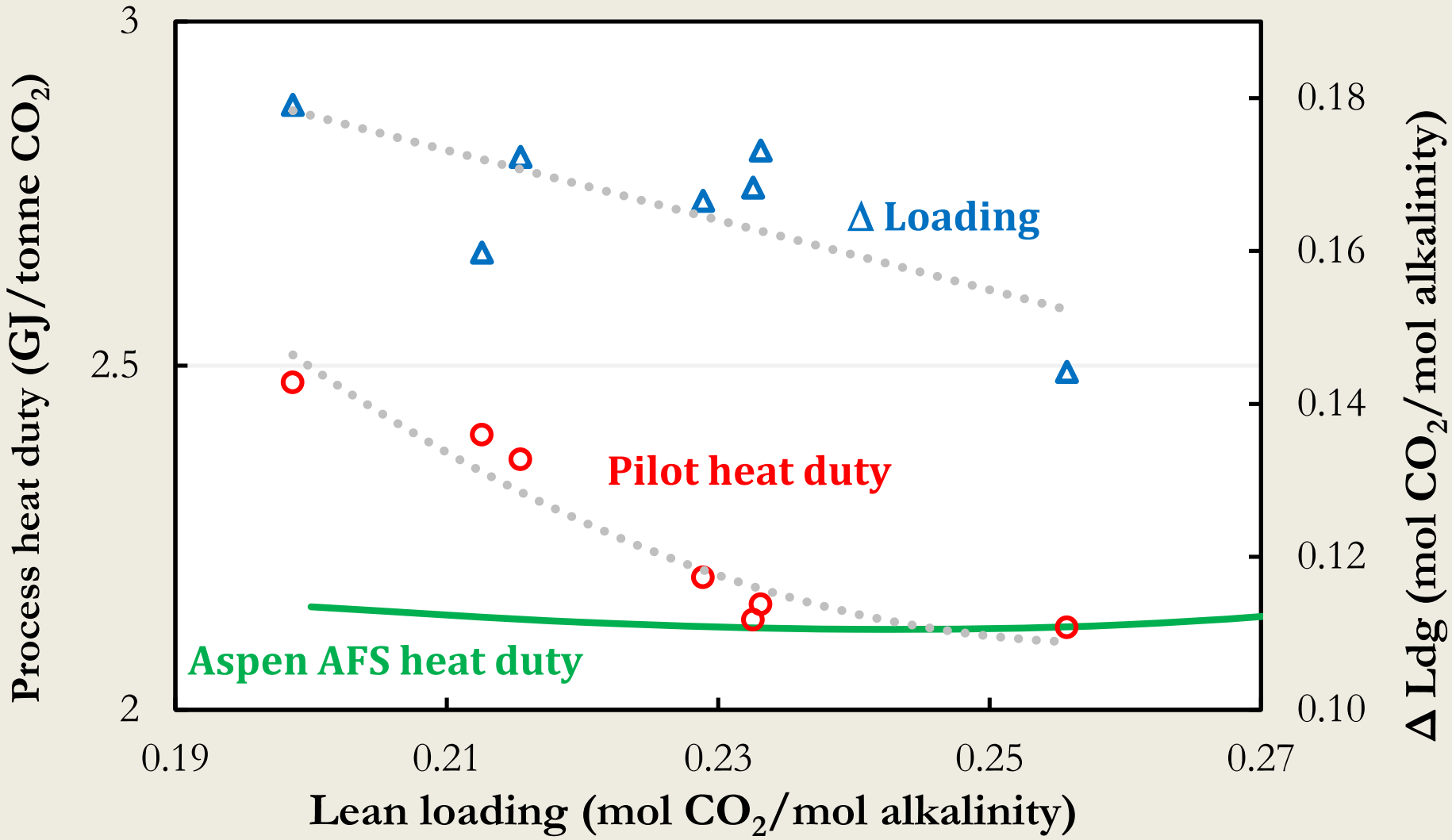


5 m vs 8 m PZ - AFS Performance

14 gpm, 145 °C, 0.24 loading

	Comparison 1		Comparison 2	
Run	8	15	9	14
PZ concentration (m)	5	8	5	8
Solvent Capacity (lb CO_2/lb solution)	0.036	0.037	0.041	0.042
Total BPS ratio	25%	24%	26%	24%
Heat Duty (GJ/tonne CO_2)	2.36	2.51	2.21	2.41
Cross X cold side DT (°F)	11.7	15.2	11.5	15.7

Effect of Lean Loading – 5 m PZ



5 m PZ vs. 8 m PZ - Absorber Performance

12% Inlet CO_2, Full Spray Intercooling

Solvent	Solvent Rate GPM	Gas Rate ACFM	Titration LLDG mol CO_2/mol alk	Measured Removal	Heat Duty GJ/tonne CO_2
5 m	14	350	0.24	96%	2.36
8 m				93%	2.51
5 m	14	500	0.24	80%	2.21
8 m				75%	2.41

- **5 m PZ higher absorption rates due to viscosity reduction**
- **Better energy performance**

PZ Absorber with Intercooling

12% Inlet CO_2, Lean Solvent Rate 14 GPM

Solvent	Gas Rate ACFM	Titration LLDG mol CO_2 /mol alk	Intercooler	Spray Nozzle	Measured Removal	Heat Duty GJ/tonne CO_2
5 m	350	0.25	N	N	80%	2.48
		0.24	Y	Y	96%	2.36
8 m	500	0.24	N	Y	68%	2.50
			Y	Y	75%	2.41

- **Intercooling is essential**
- **Mass transfer enhancement by Spray Nozzle**
- **Better energy performance**

PZ Over-Stripping without Intercooling

5 m PZ, 12% Inlet CO_2, Gas Rate 350 ACFM

Solvent Rate	Titration LLDG	Intercooler	Spray Nozzle	Measured Removal	Heat Duty
GPM	mol CO_2/mol alk				GJ/tonne CO_2
8.6	0.18	N	N	84%	2.48
14	0.25	N	N	80%	2.48

- **First time running over-stripping LLDG in Pilot Plant**
- **No solid precipitation observed**
- **Able to achieve adequate removal with comparable energy performance**

Conclusions

- Advanced Flash Stripper
  - 17 run: 2.1-2.5 GJ/ton CO_2 (5 m PZ)
  - 4 runs: 2.5-2.9 GJ/ton CO_2 (8 m PZ)
  - 25% heat duty reduction vs past campaigns (2SF)
  - Optimized rich solvent bypass reduced heat duty by 15%
  - 5 m PZ reduced duty because better heat transfer performance than 8 m PZ (viscosity)
- Absorber
  - 5 m vs 8 m PZ ~ 5% higher CO_2 removal
  - IC = 90 – 98% CO_2 removal
  - No IC = 68 – 84% CO_2 removal

Acknowledgements

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