Pilot Plant Testing of Piperazine (PZ) with Advanced Flash Regeneration

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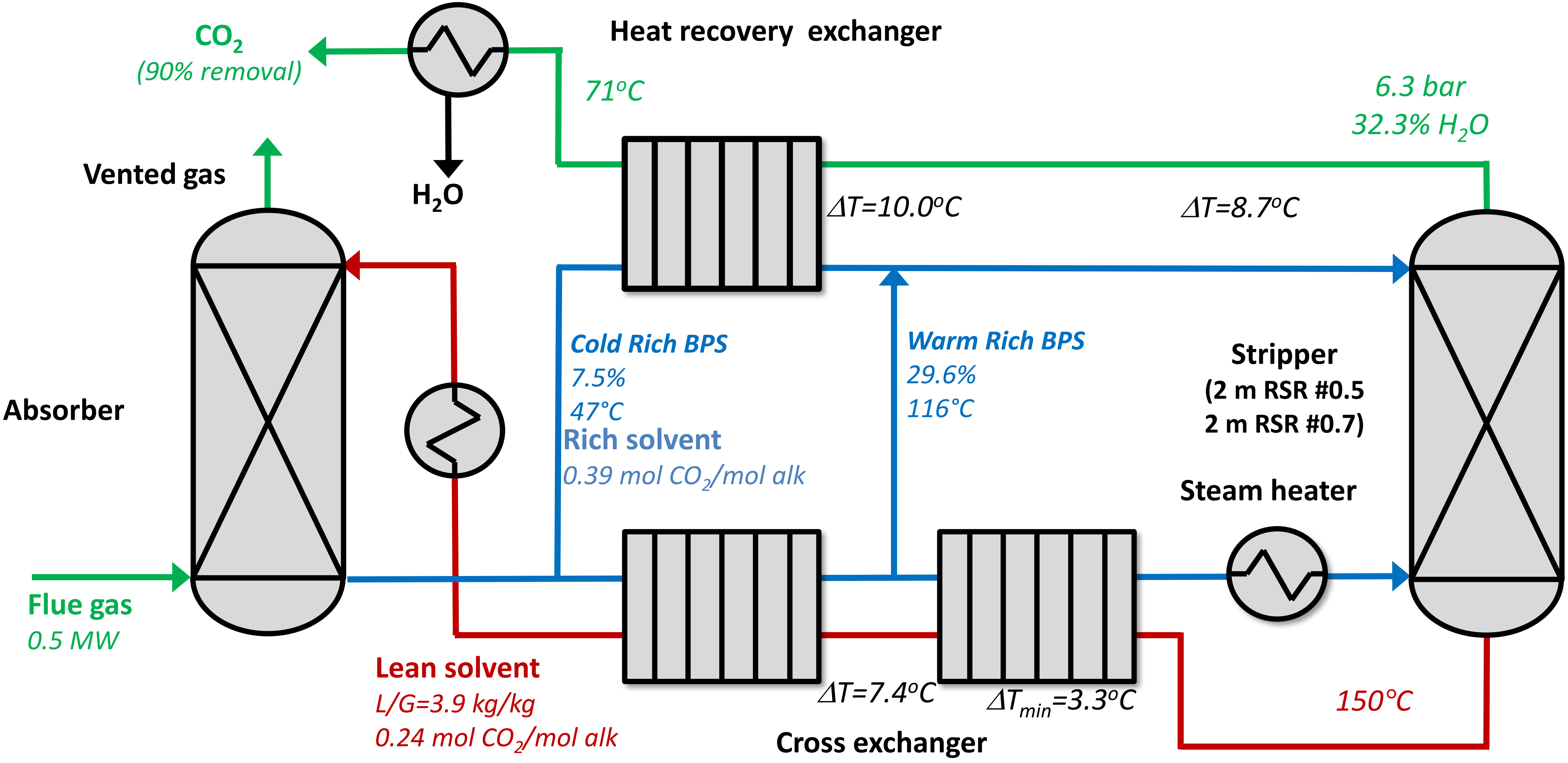
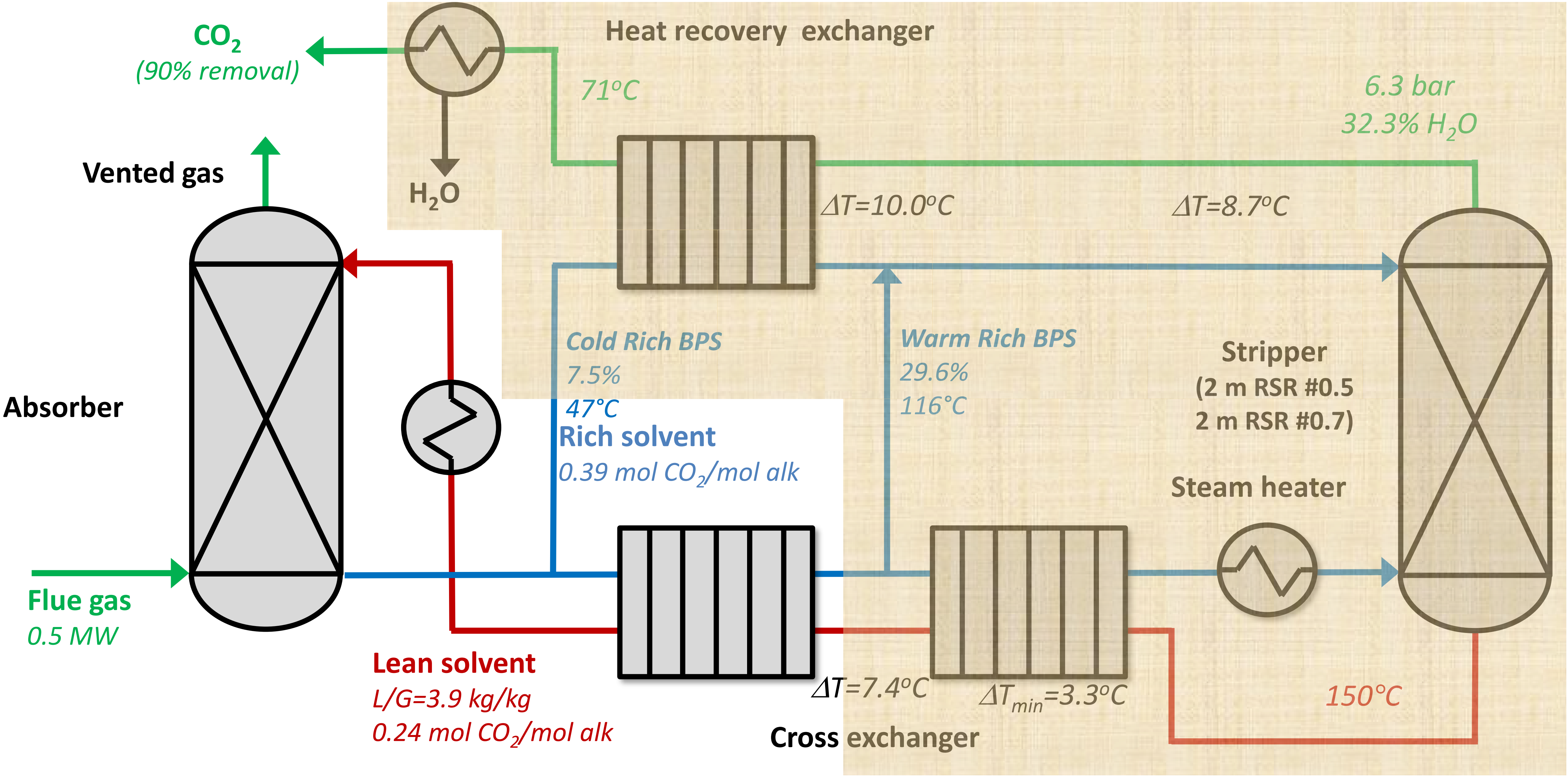
Advanced Flash Stripper (AFS)



New Equipment on Skid



Outline

- Funding and objectives : NCCC fall 2017
- Capital and Energy << MEA
- Solvent Management of PZ - Prepared

Project Budget ($million)

	BP1	BP2	Total
Federal	1.6	3.3	5.2
Cost Share	1.1	0.3	1.5
Total	2.7	3.6	6.7

Cost share by CO_2 Capture Pilot Plant Project (C2P3)

Objective is to develop PZ with advanced regeneration at 150°C

PZ	• Optimize solvent (8m vs 5m) • Demonstrate resistance to oxidation, nitrosation, & corrosion
Regeneration	• Two stage flash (2SF) • Advanced flash stripper (AFS)
Aerosols	• Formation and control • Characterization

Phased testing at UT SRP and NCCC to optimize PZ absorption/regeneration

SRP 2011
- 2SF
- 8m PZ

Completed

SRP 2013
- 1SF
- 5m PZ
- Aerosol

Completed

SRP 2015
- AFS
- 5 vs 8m
- Aerosol

Completed

0.1 MW

CO_2 in air

BP1

Phased testing at UT SRP and NCCC to optimize PZ absorption/regeneration

SRP 2017

- AFS
- 5m PZ
- 4-20% CO_2
- Aerosol
- Corrosion

Completed MTR/DOE

NCCC 2017

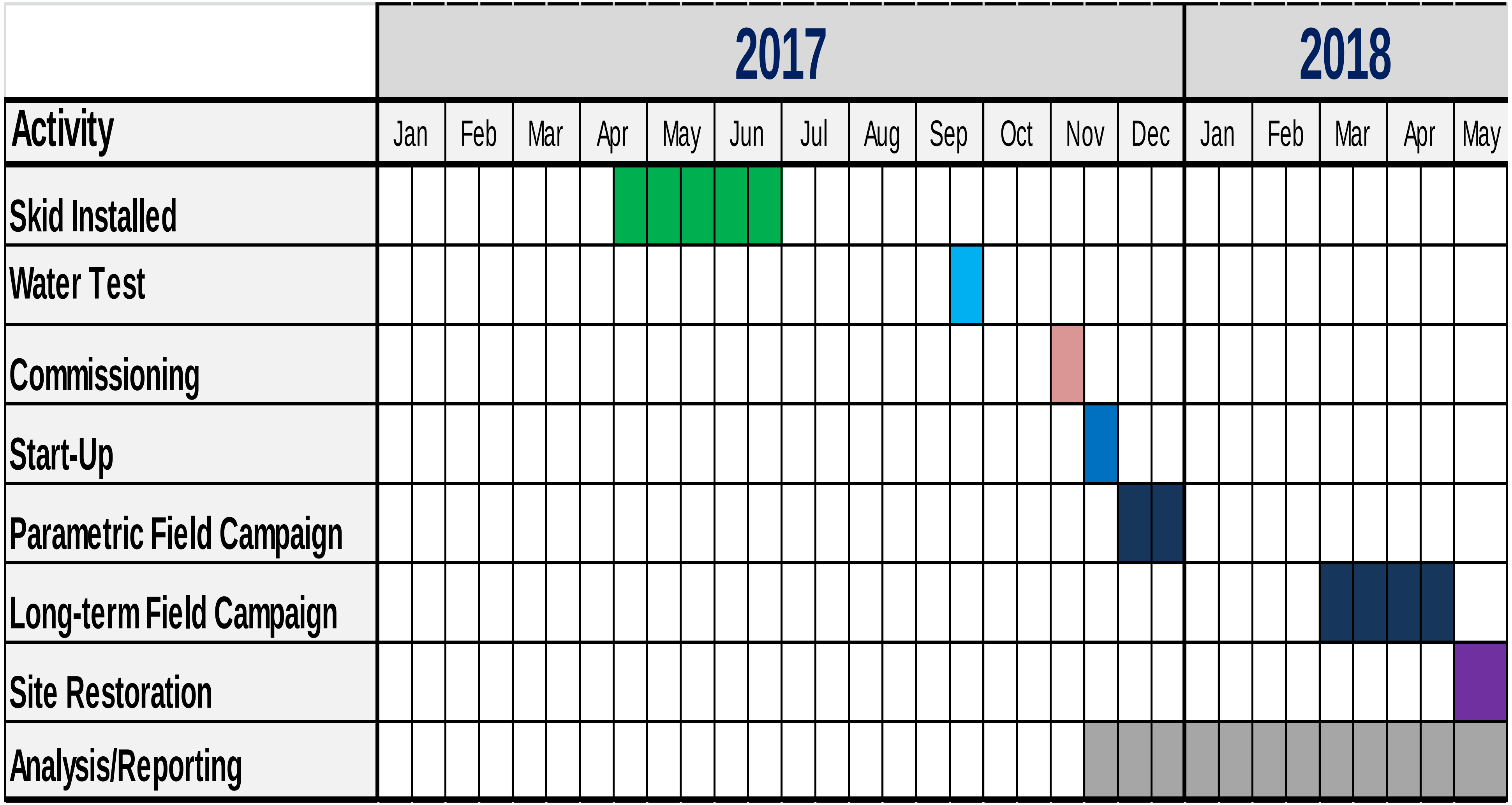
- AFS
- 5m PZ
- Aerosol
- Corrosion
- Oxidation

Ready to operate

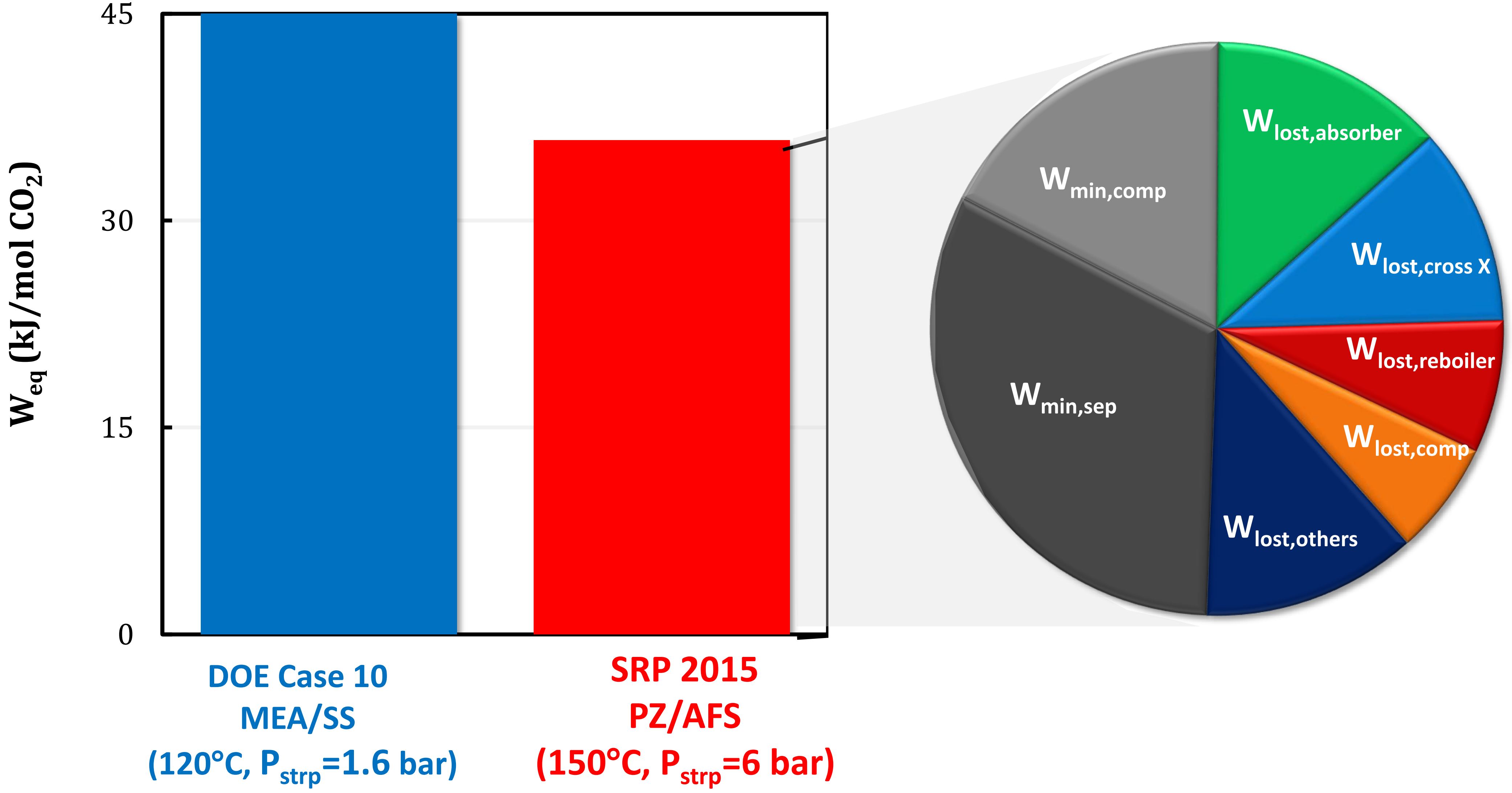
0.1 MW **CO_2 in air**	**0.5 MW** **Flue gas**
MTR/DOE BP2	**AECOM/DOE BP2**

Our test window:

Fall 2017 parametric
Spring 2018 long-term



Advanced amine scrubbing gives 50% efficiency
Limited by capital-energy tradeoff

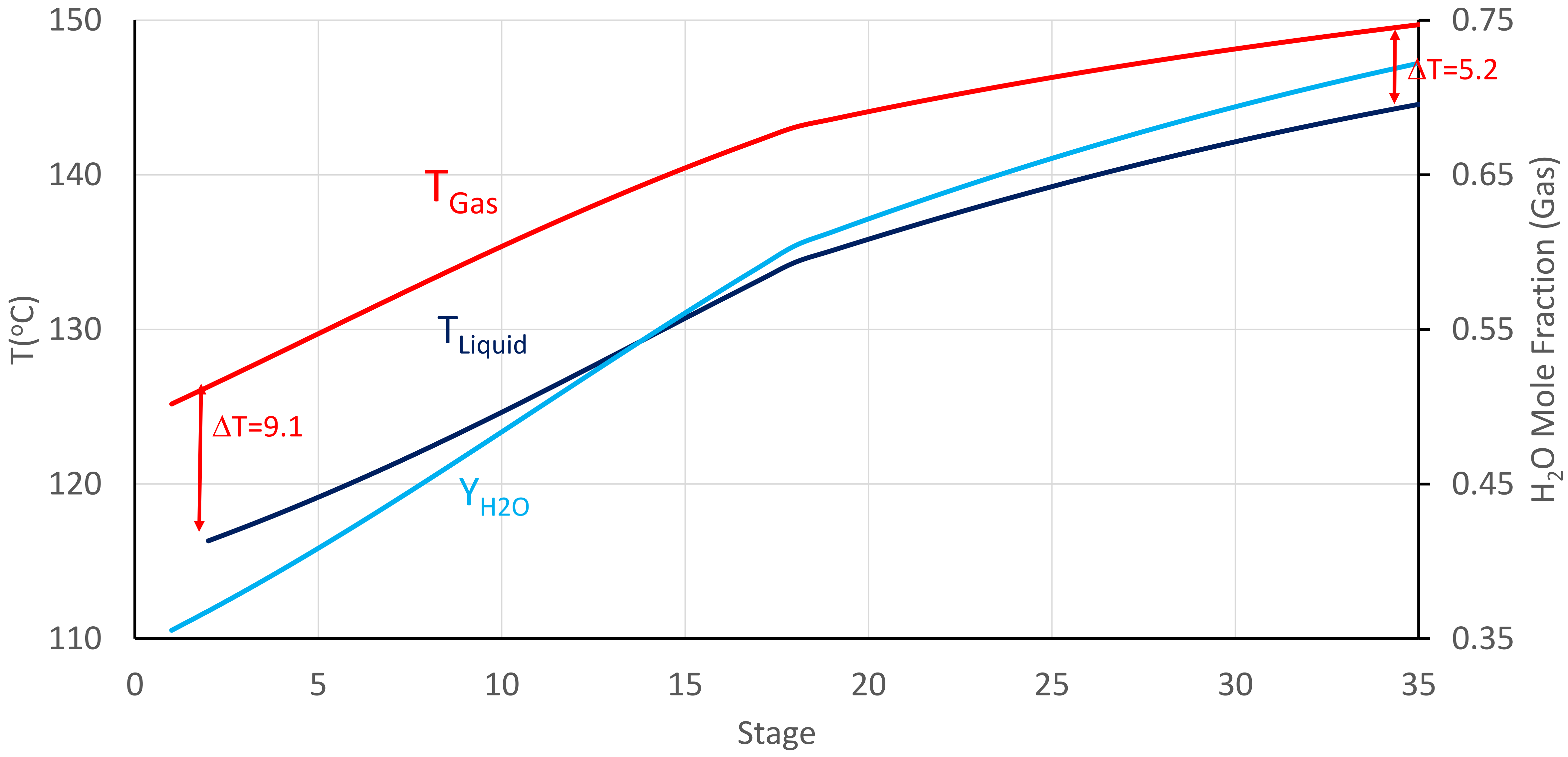


AFS also works with other solvents

Solvent	kg' (10^{-7}mol/Pa-s-m^2)	W_{eq}(kJ/mol CO_2) Simple stripper	AFS
7m MEA	4.3	36.3	32.7
10m DGA	3.6	37.0	34.2
8m PZ	8.5	34.9	31.4
5m PZ	11.3	36.5	32.3
2m PZ /3m HMPD	10.1	34.9	**31.0**

- $Rich\ P^*_{CO_2} = 5\ kPa, Lean\ P^*_{CO_2} = 0.2\ kPa$
- Optimum cross exchanger $\Delta T_{LM} = 5K \left(\frac{\mu}{\mu_{MEA}}\right)^{0.175}$

AFS provides reversible stripper performance
90% removal, 0.24 lean ldg



Possible long term conditions at NCCC

0.24 lean ldg, 150°C/82 psia stripper, 2x20 ft absorber packing

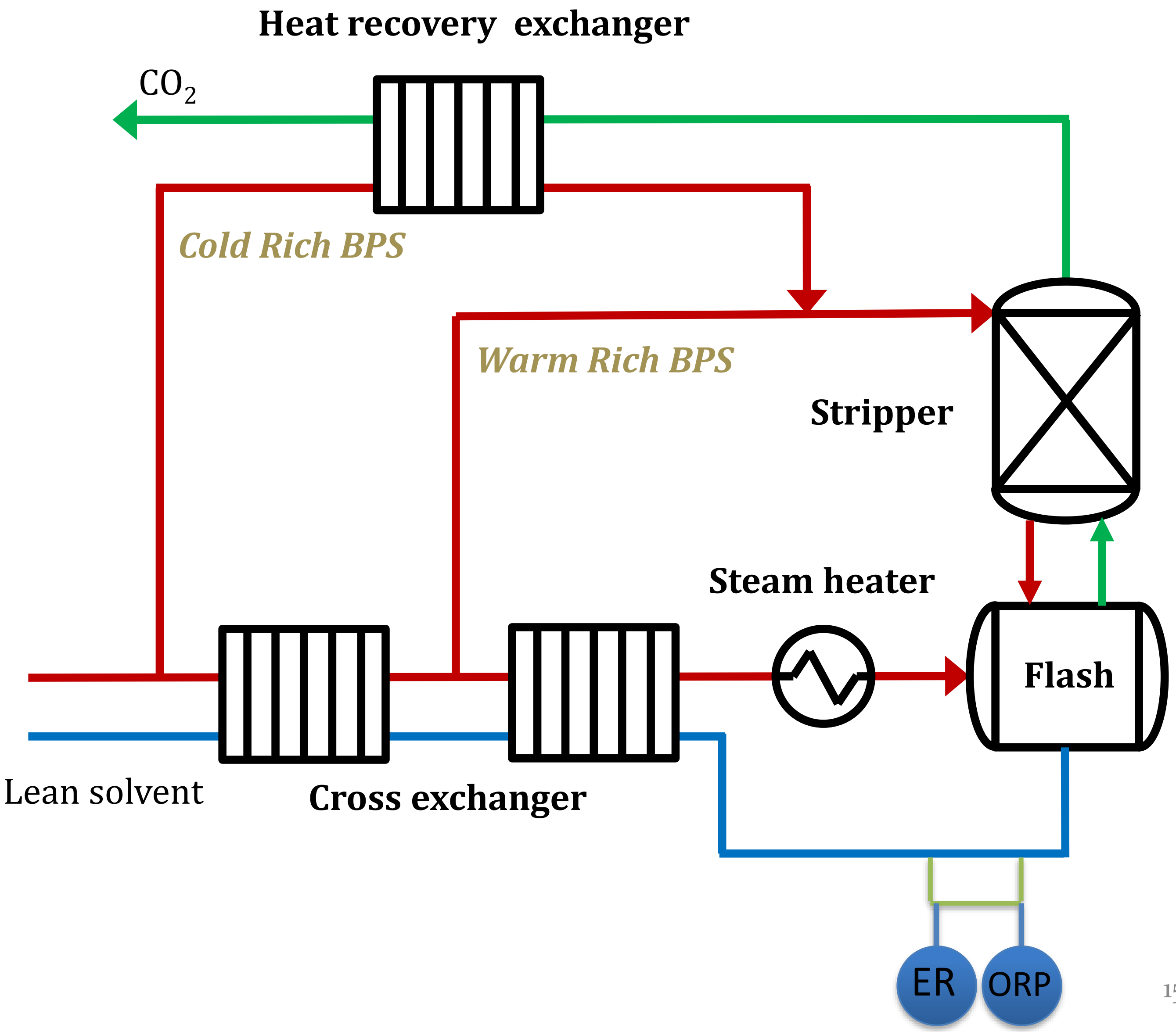
CO_2 removal (%)	Gas Rate (MW)	Rich Ldg (mol CO2/eq PZ)	L/L_{min}	W_{eq} (kwh/tonne)	Q (GJ/tonne)
90	0.5	0.387	1.006	256	2.56
98.5	0.5	0.366	1.16	260	2.61
95.4	0.8	0.380	1.10	274	2.77

PZ losses and environmental impact

- Resistant to corrosion, use more carbon steel
- Moderate volatility
  - Manage losses with water wash
  - Manage impurities with thermal reclaiming
- Manage aerosol with grow and capture
- Resistant to Degradation
  - Thermally stable to 150°C
  - Oxidation, 4x less than MEA
  - Nitrosation, decompose at 150°C
- Manage solid precipitation with rich storage

SRP Pilot Plant Corrosion 2017

- Two ER corrosion probes in stripper
  - 316L SS
  - 1010 CS
- One ORP Probe
- In addition, one ER probe in absorber sump



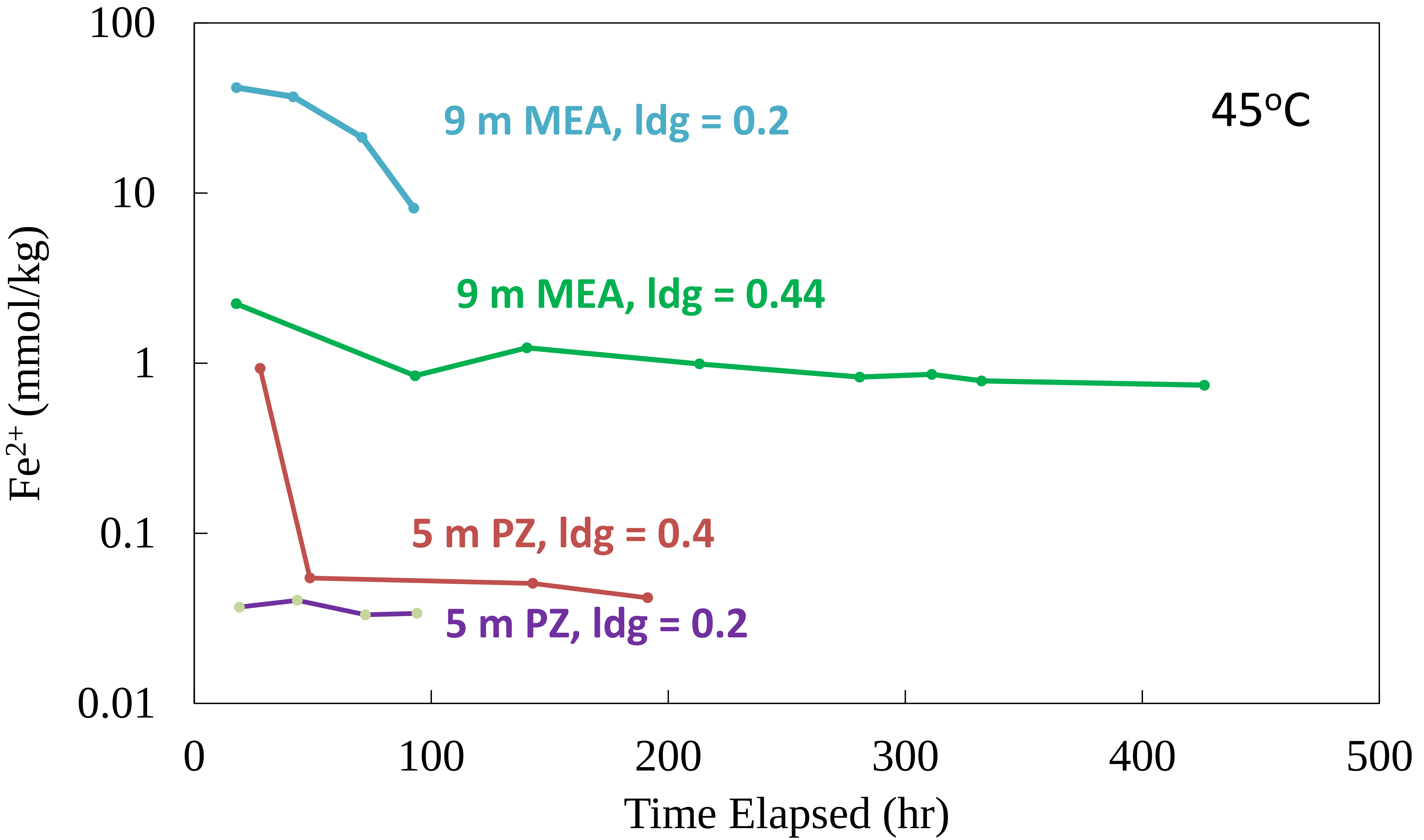
SRP Pilot Plant Corrosion 2017

Location	**Alloy**	T (°C)	Avg. Loading (mol CO_2/mol N)	**Corrosion (μm/yr)**
Absorber	**C1010**	30	0.33	**331**
Stripper	**C1010**	150	0.21	**325**
Stripper	**316L**	150	0.21	**174**

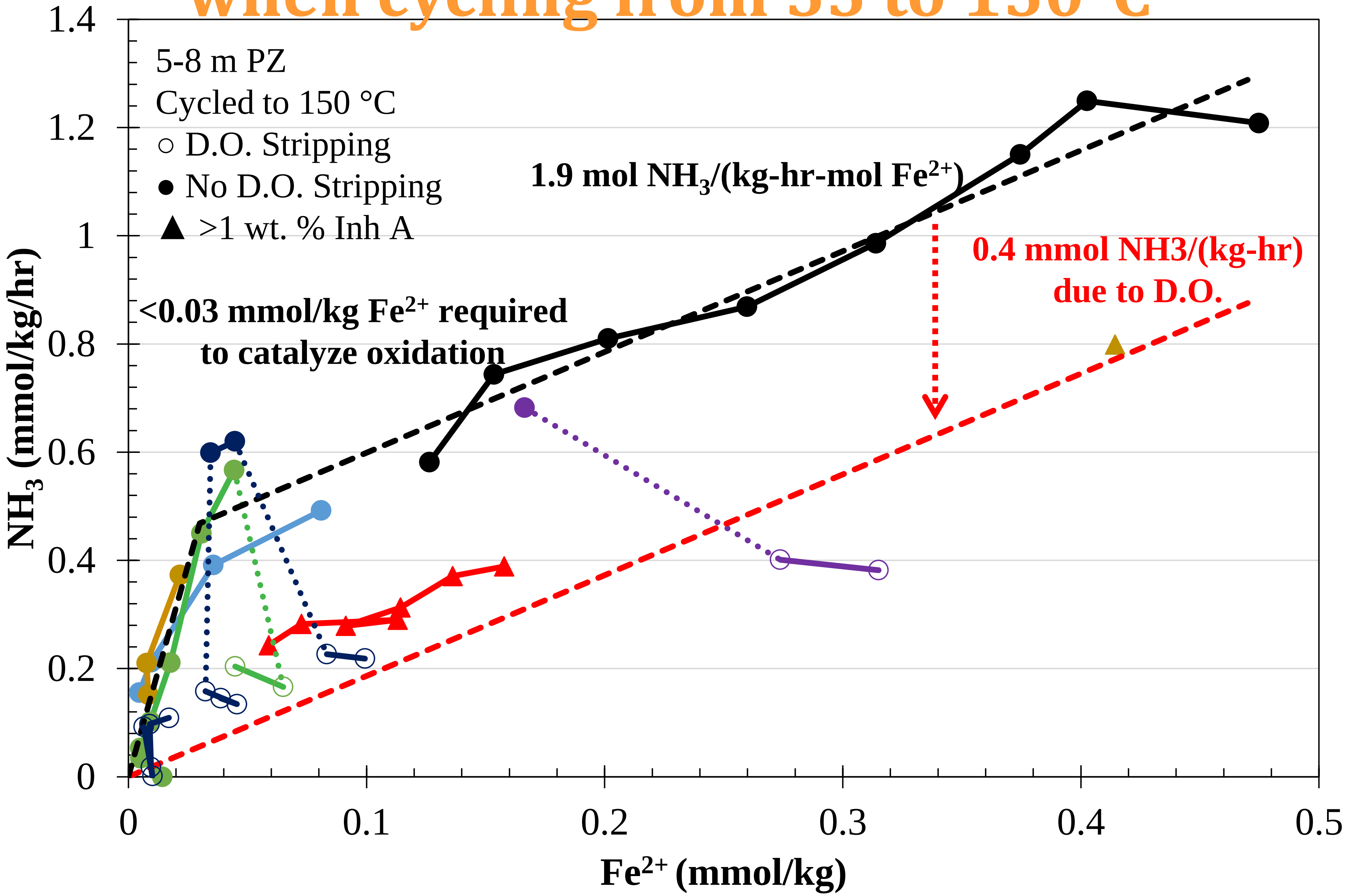
- Absorber corrosion greater than expected

Corrosion (μm/yr)	
Good	100 - 500
Poor	1000 - 5000
Unacceptable	5000+

- Low Fe^{2+} solubility in PZ may result in $FeCO_3$ protective layer.



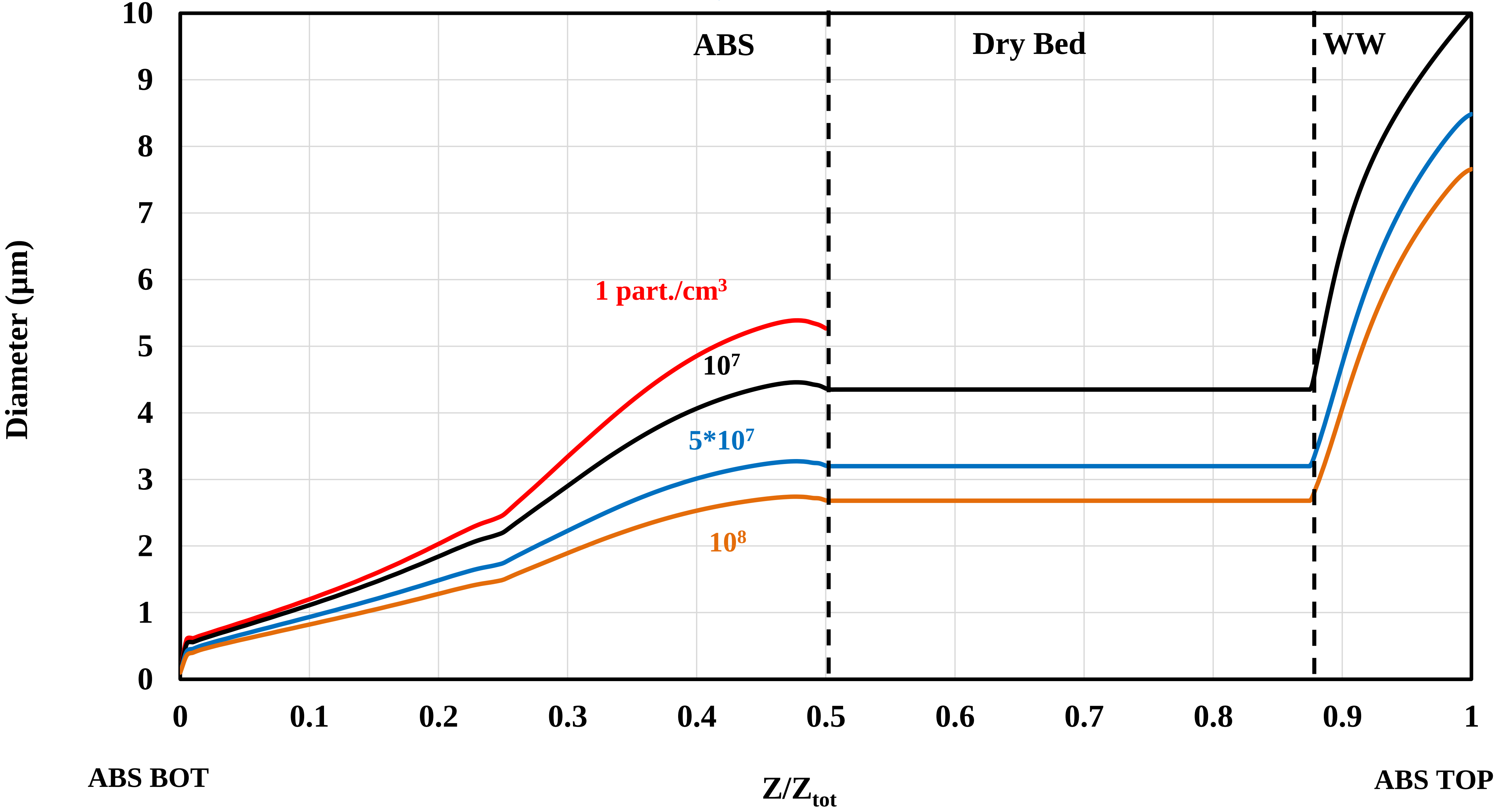
Dissolved oxygen and metals increase oxidation when cycling from 55 to 150°C



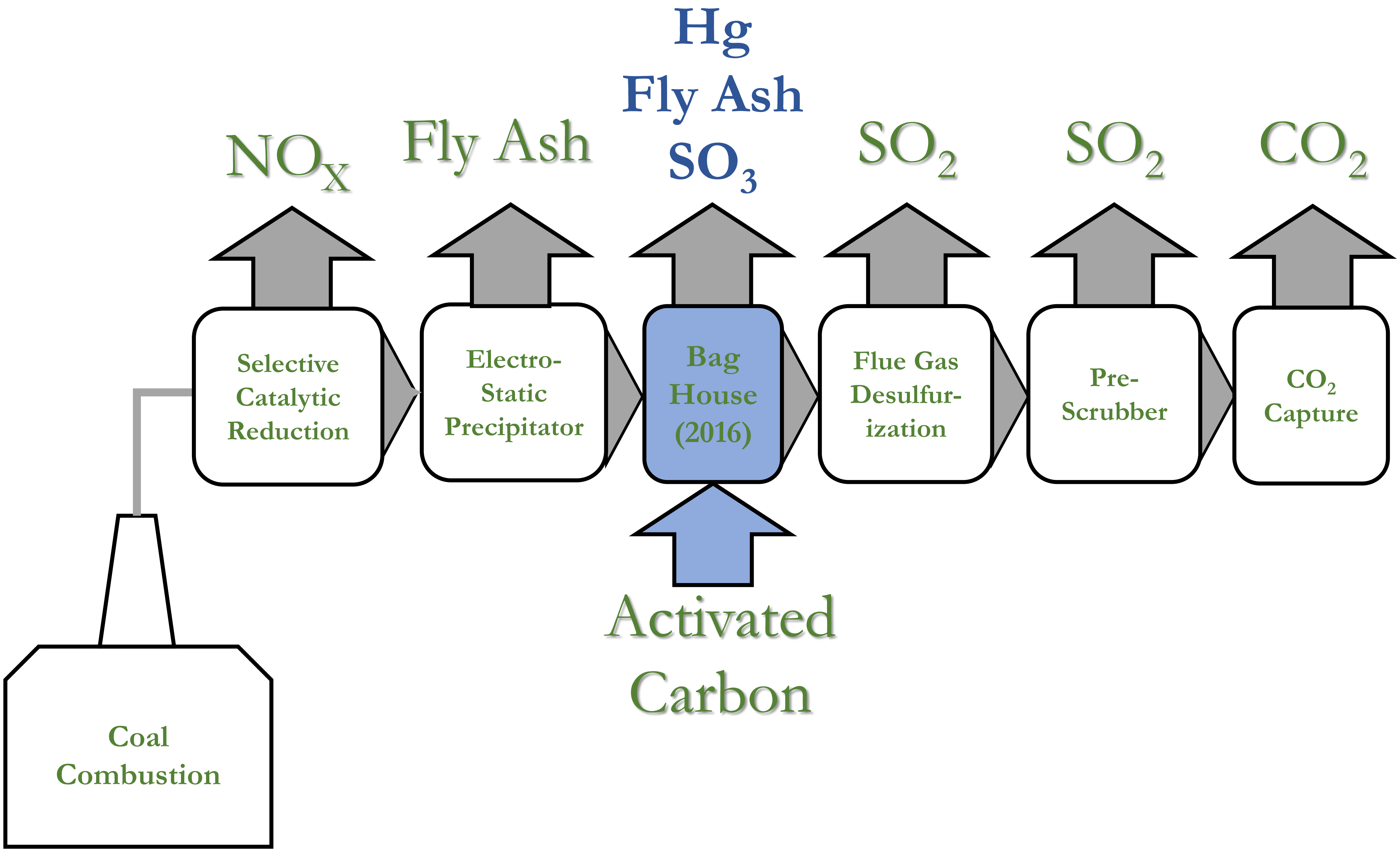
Oxidation Mitigation

- Reaction w D.O.: 0.05 mmol/kg/cycle in HTOR
  - Minimize holdup at high temperature before stripper
  - Strip O_2 with N_2 mmol/(kg-cycle-mmol/kg Fe^{2+})
- Fe^{2+} solubilized by degradation products
  - Oxidation → Fe^{2+} accumulation → more oxidation
  - NO_2 → MNPZ → Oxidation in pilots w/ coal flue gas
    - Prescrub NO_2 and reclaim solvent to minimize Fe^{2+}

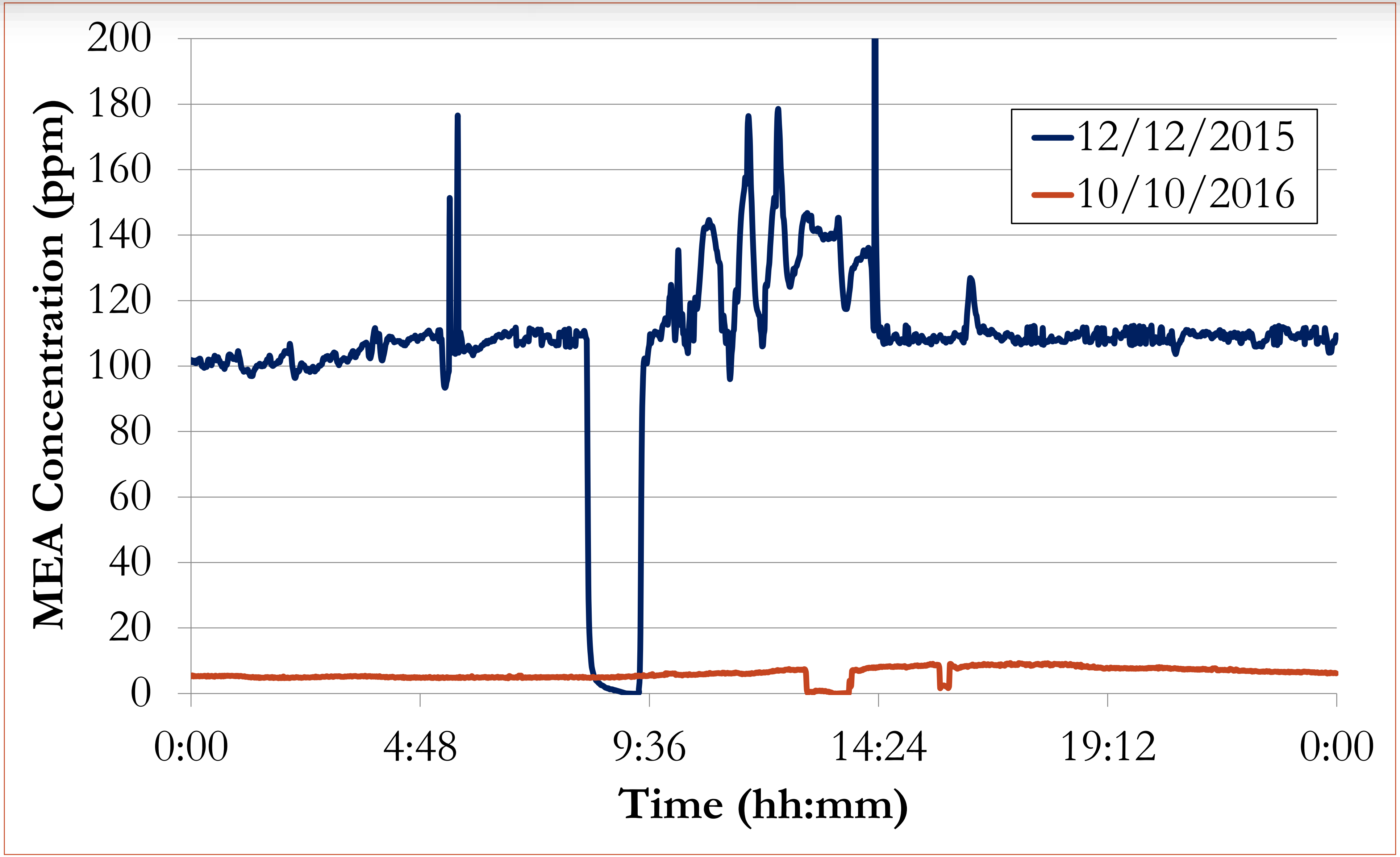
Growth slows down at high part. number conc
5 m PZ, NCCC conditions



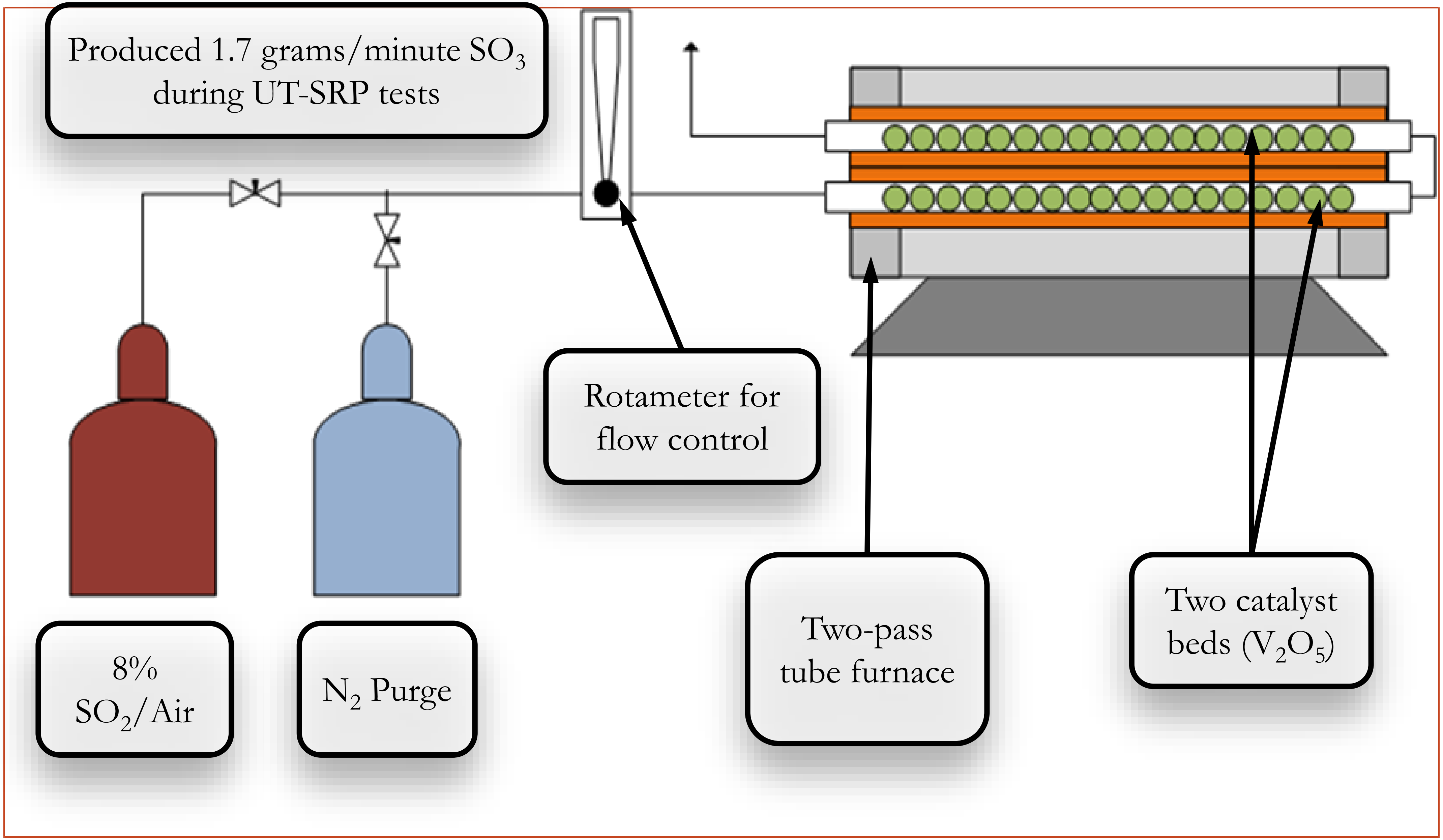
Baghouse at NCCC

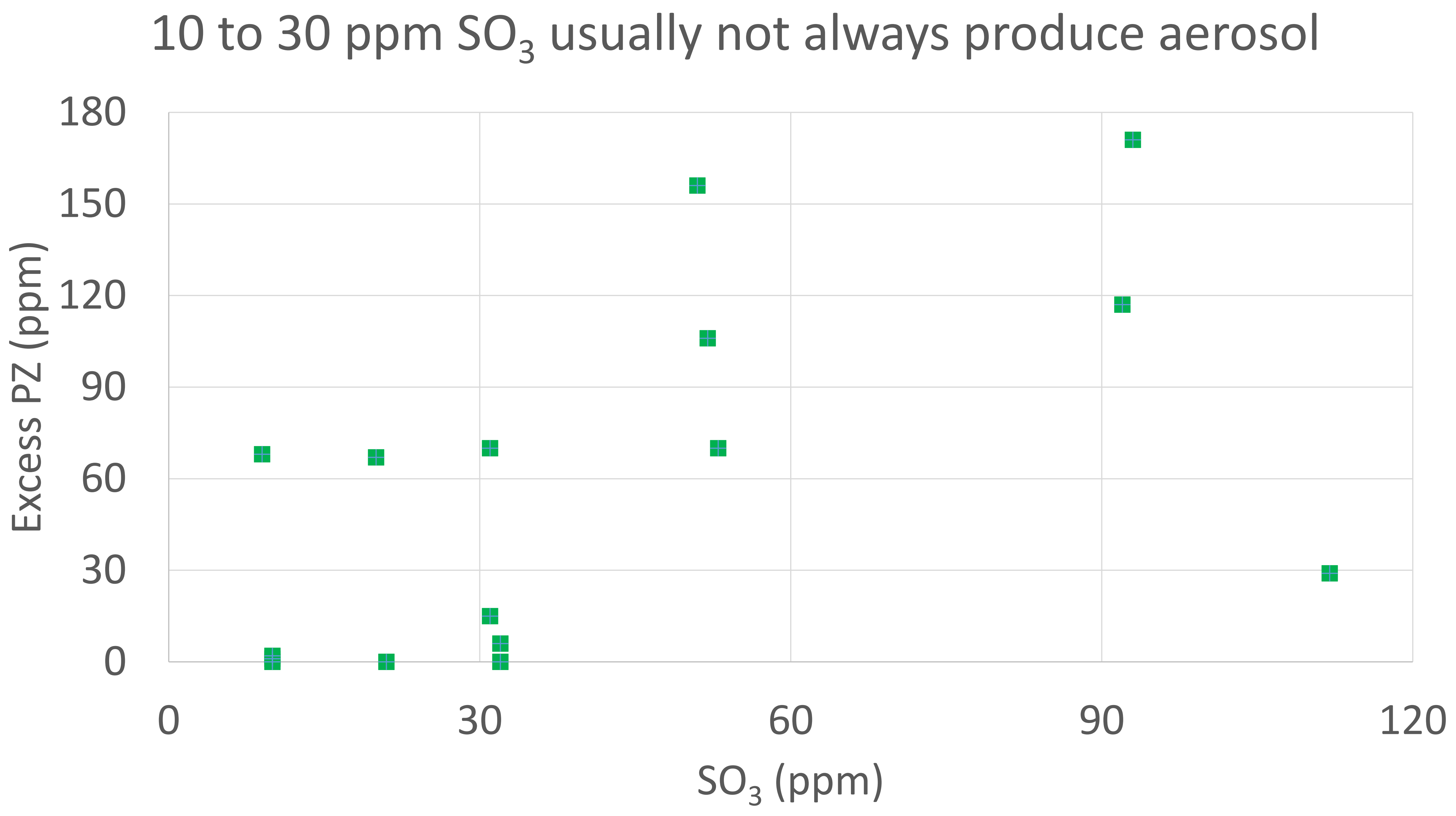


Baghouse at NCCC significantly reduced MEA emissions



SO_3 Generation




10 to 30 ppm SO3 usually not always produce aerosol
180
150
120
90
60
30
0
Excess PZ (ppm)
0
30
60
90
120
SO3 (ppm)

Conclusions

- The Advanced Flash stripper will reduce W_{eq} by 10-20% for PZ and other solvents
- 5 m PZ is a superior solvent
  - Fast absorption, thermally stable, high P stripper
  - Good resistance to corrosion, oxidation
  - Managed aerosol

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