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

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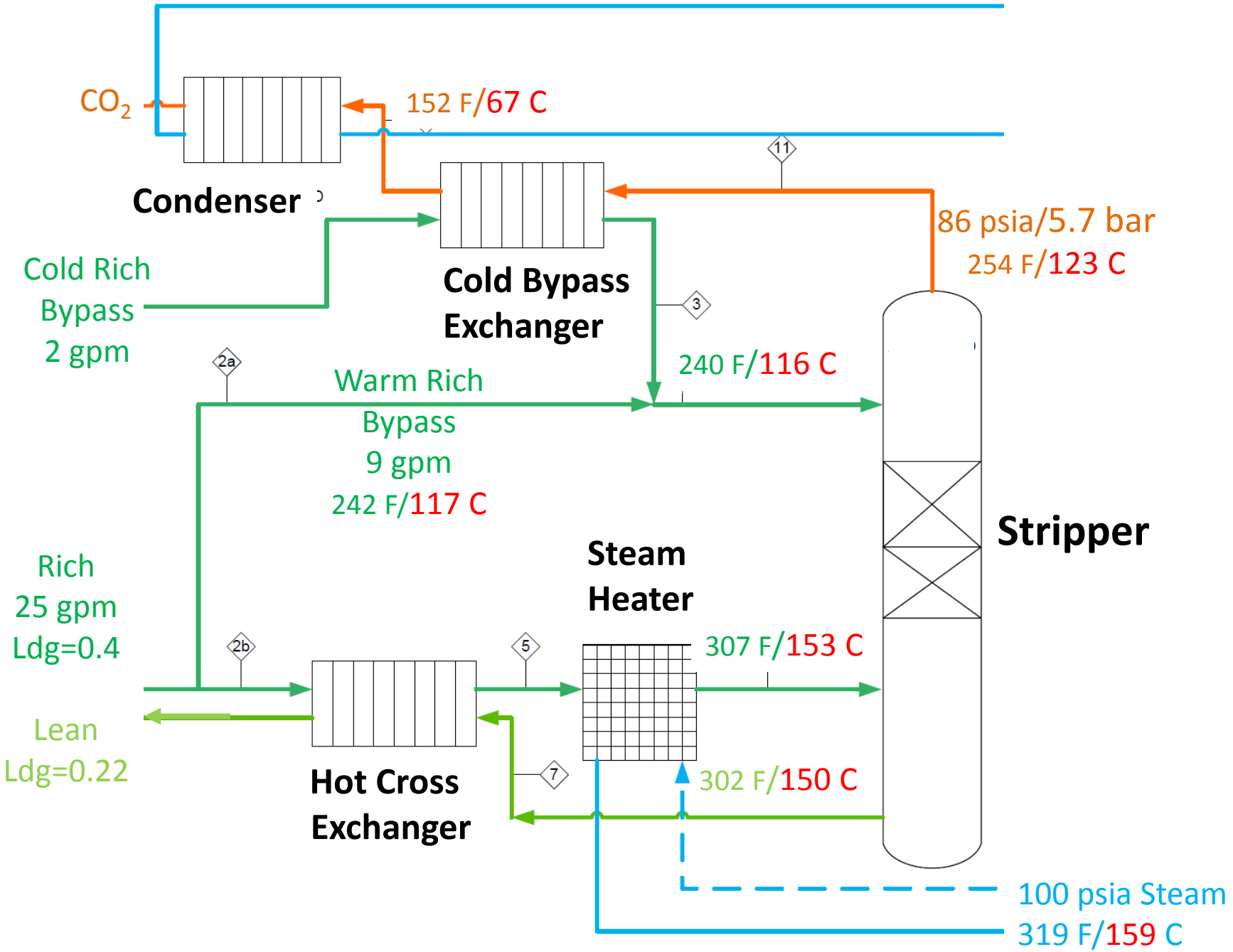
Advanced Flash Stripper with 5 m PZ for NCCC



Outline

- Funding and objectives : NCCC summer 2017
- Equipment for NCCC: small stripper
- Capital and Energy << MEA
- Solvent Management of PZ - prepared

Project Budget ($million)

	BP1	BP2	Total
Federal	1.6	3.0	4.7
Cost Share	1.1	0.3	1.3
Total	2.7	3.3	6.0

Cost share by CO_2 Capture Pilot Plant Project (C2P3)

EPRI ELECTRIC POWER RESEARCH INSTITUTE

LG&E KU

B&W thebabcock&wilcoxcompany

Luminant

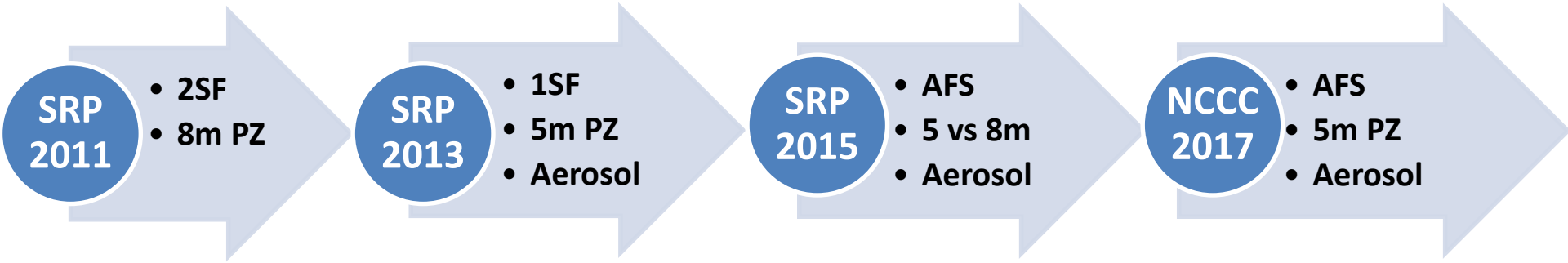
SOUTHERN COMPANY

Chevron Human Energy

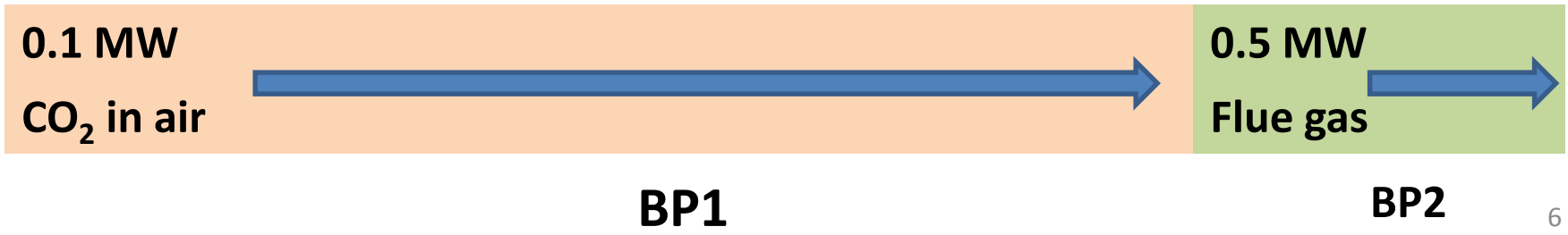
Objective is to develop PZ with advanced regeneration at 150°C

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

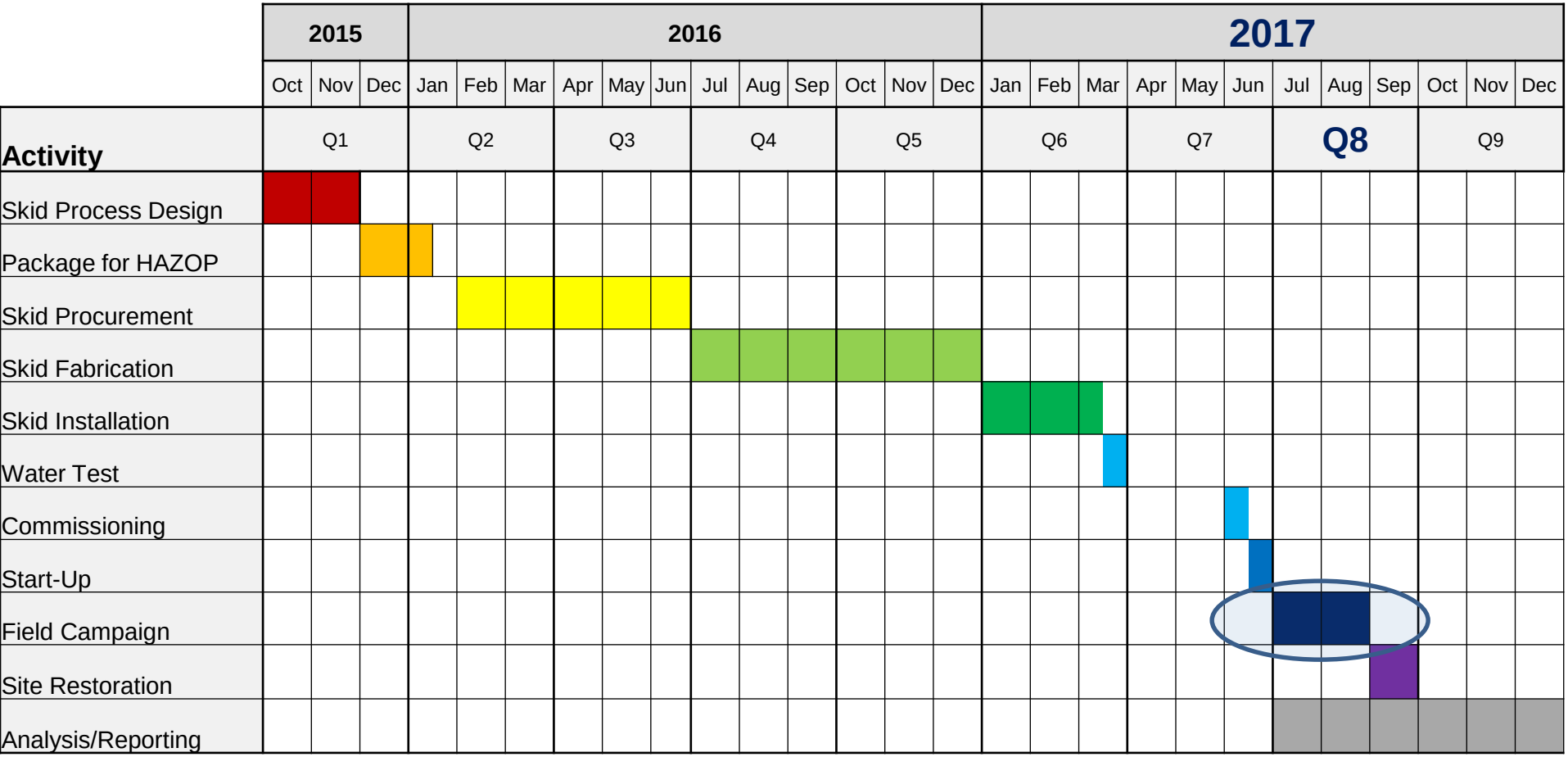
Phased testing at UT SRP and NCCC to optimize PZ absorption/regeneration



Completed | Completed | Completed | Construction in progress



Our test window: Jun-Aug 2017



Contactors (to scale)

NCCC
Default

AFS
5 m PZ

107 ft
26 inch
60 ft packing

Absorber

74 ft
18 inch
40 ft Packing

Stripper

40 ft
packing

Absorber

33 ft
10/20 inch
13 ft packing

Stripper

AFS Heat Exchangers

Application	Q (kBt/uhr)	Side (inches^2)	Volume (ft^3)	Type
Stm heater	650	32x32	17	Compabloc
Hot Cross	644	85x61	104	P&F
Cold Rich	143	25x51	17	P&f
Condenser	28	22x36	10	P&F
Cold Cross (existing)		102 x 78	147	P&F

5m PZ/AFS has lowest costs of configurations modeled by UT

- PZ/AFS = $39.03/tonne (no TS&M)
- Econamine = $56.47/ton (no TS&M)

TEA per Rev2a, Case 12

Capital Cost < MEA w Simple Stripper

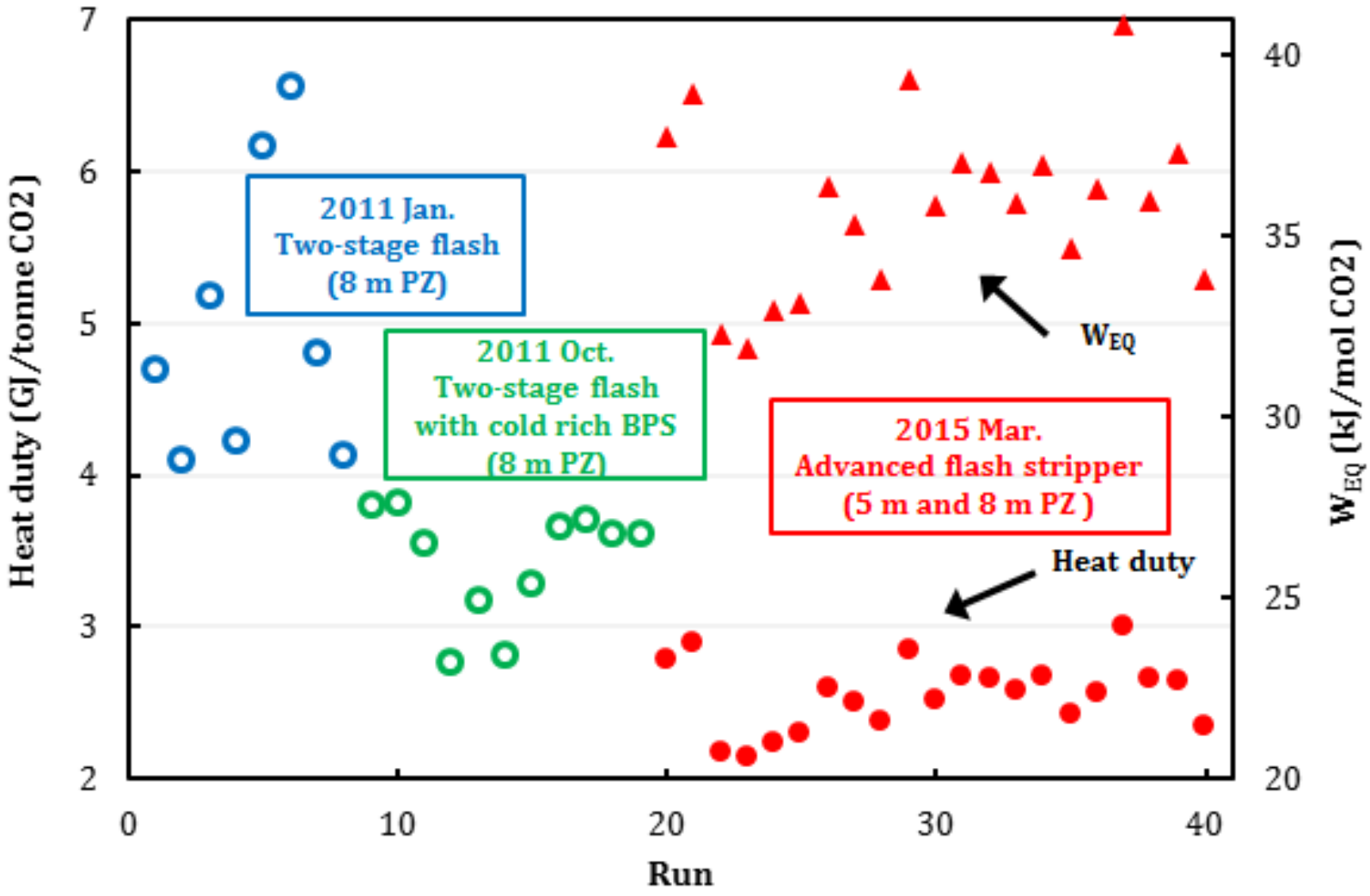
AFS < Simple stripper

- Total exchanger duty of AFS ≤ Simple stripper
- Total no. of exchangers of AFS ≈ Simple stripper
  - Size limited so multiple exchangers are needed
  - Arrange in series rather than parallel

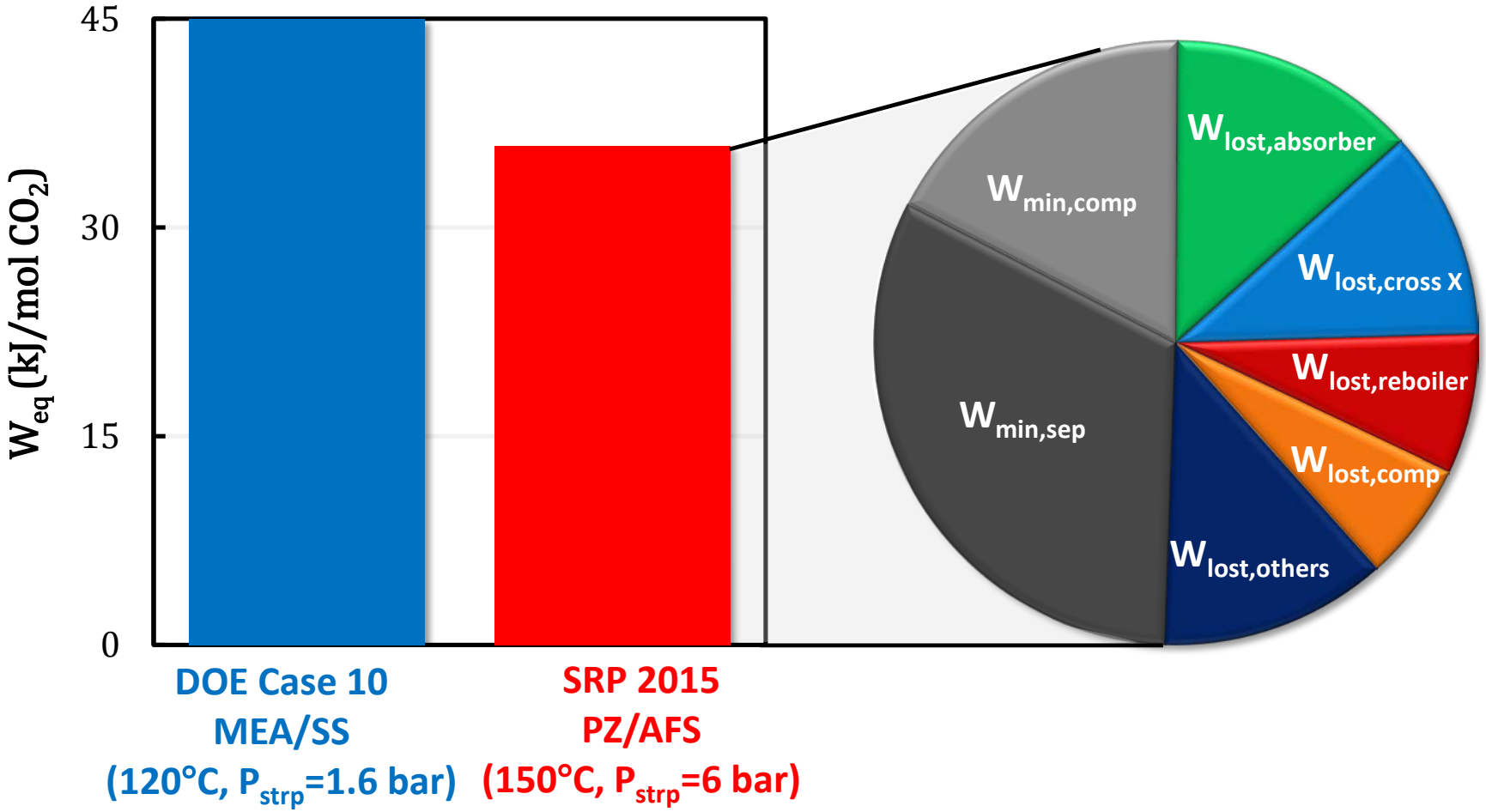
5 m PZ < 7 m MEA

- Absorber for PZ<MEA (2 x faster absorption)
- Stripper for PZ<MEA (2-3 x greater P & $<Q_{reb}$)
- Compressor for PZ<MEA (2-3 x greater P)

AFS reduced energy requirement by 25%



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



Advanced Flash Stripper with other solvents

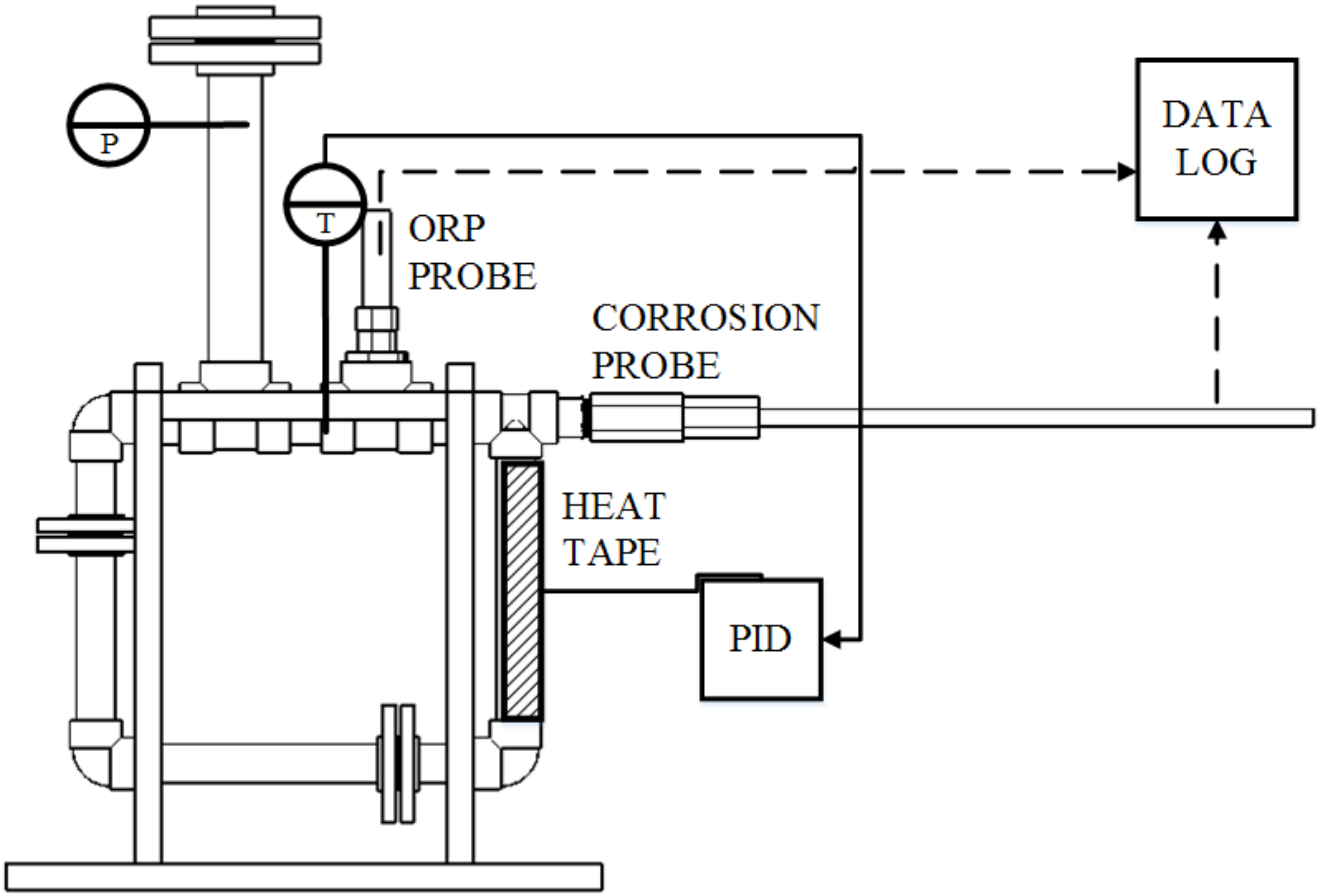
Solvent	kg' (10^{-7}mol/Pa-s-m^2)	W_{eq}(kJ/mol CO_2)	
		Simple stripper	AFS
7m MEA	4.3	36.3	32.7
10m DGA	3.6	37.0	34.2
8m PZ	8.5	34.9	31.4
5m PZ	11.3	36.5	32.3
2m PZ /3m HMPD	10.1	34.9	**31.0**

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

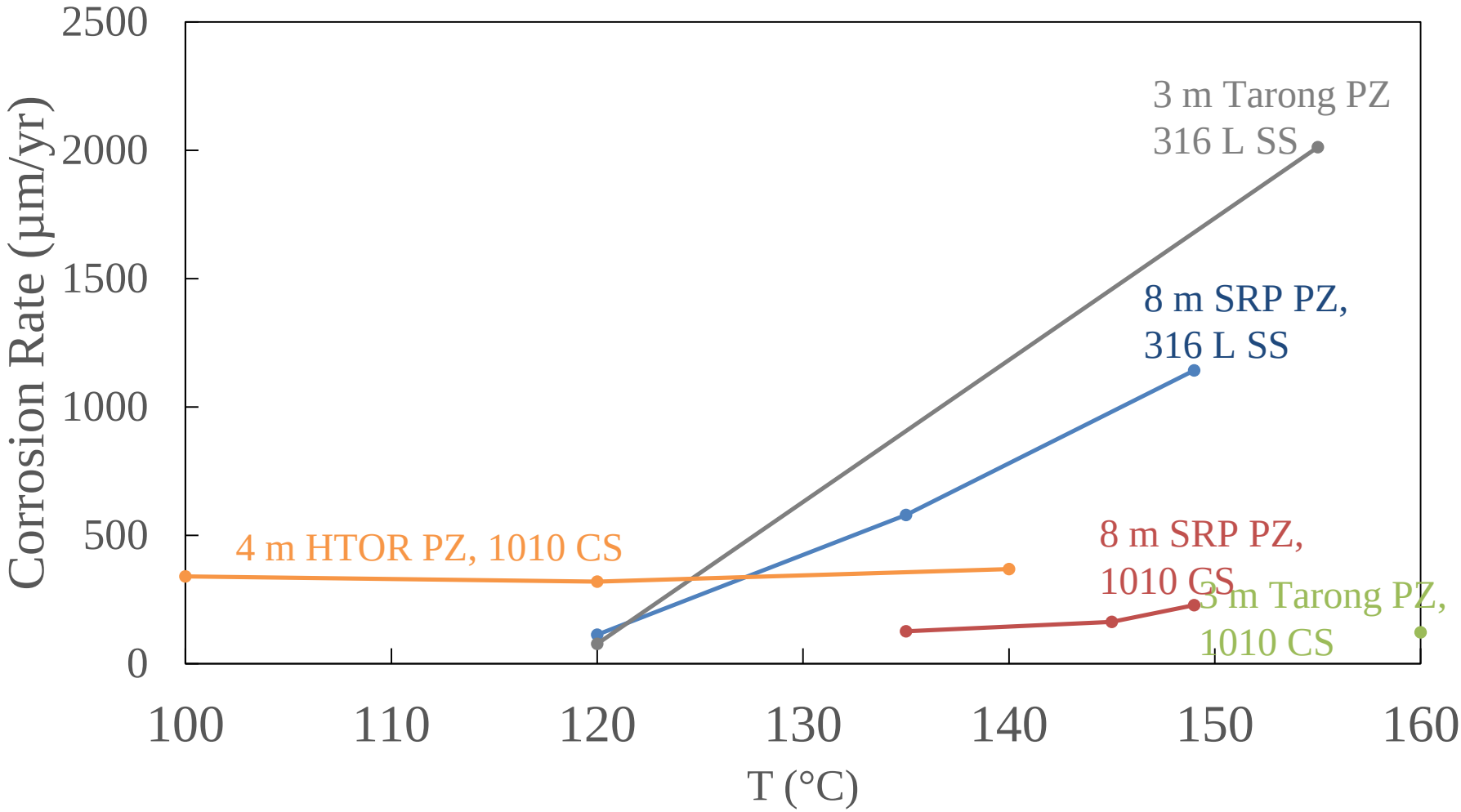
PZ losses and environmental impact

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

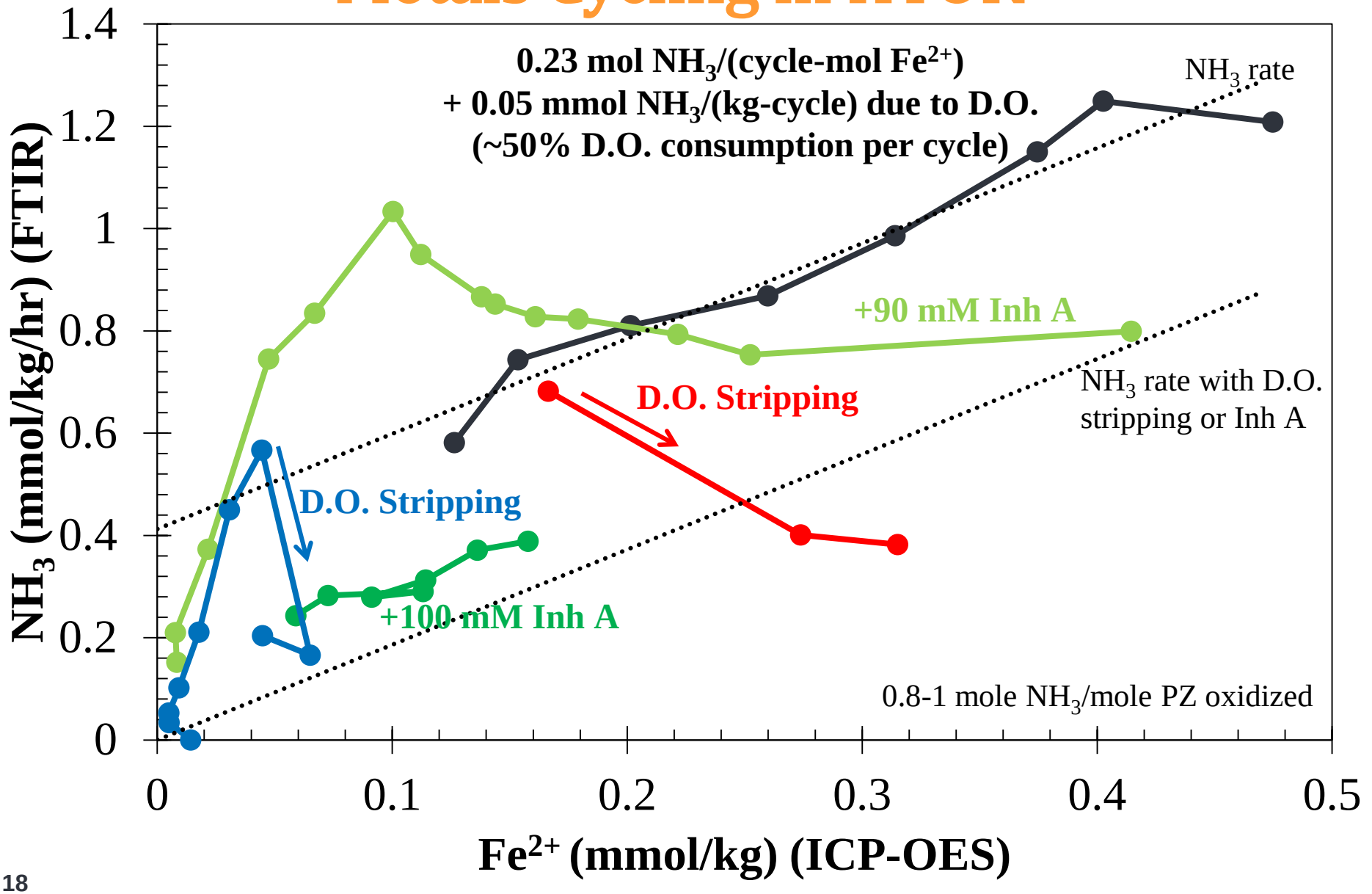
Laboratory Corrosion Apparatus



Corrosion at stripper T, no O_2



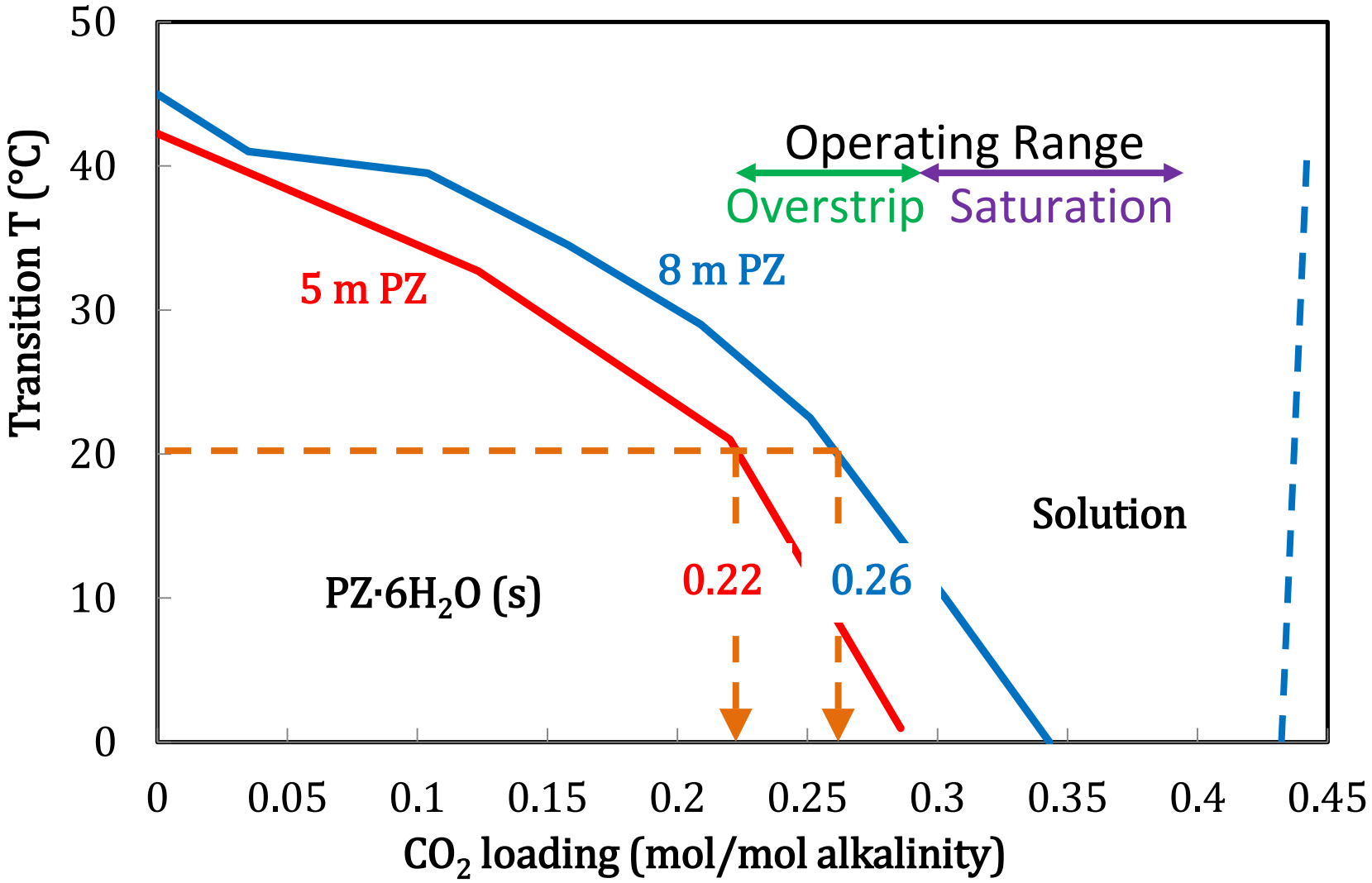
D.O. Consumption and Metals Cycling in HTOR



Oxidation Mitigation

- Reaction w D.O.: 0.05 mmol/kg/cycle in HTOR
  - Minimize holdup at high temperature before stripper
- Metals cycling: +0.23 mmol/(kg-cycle-mmol/kg Fe^{2+})
  - Fe^{2+} solubilized by accumulation of 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+}

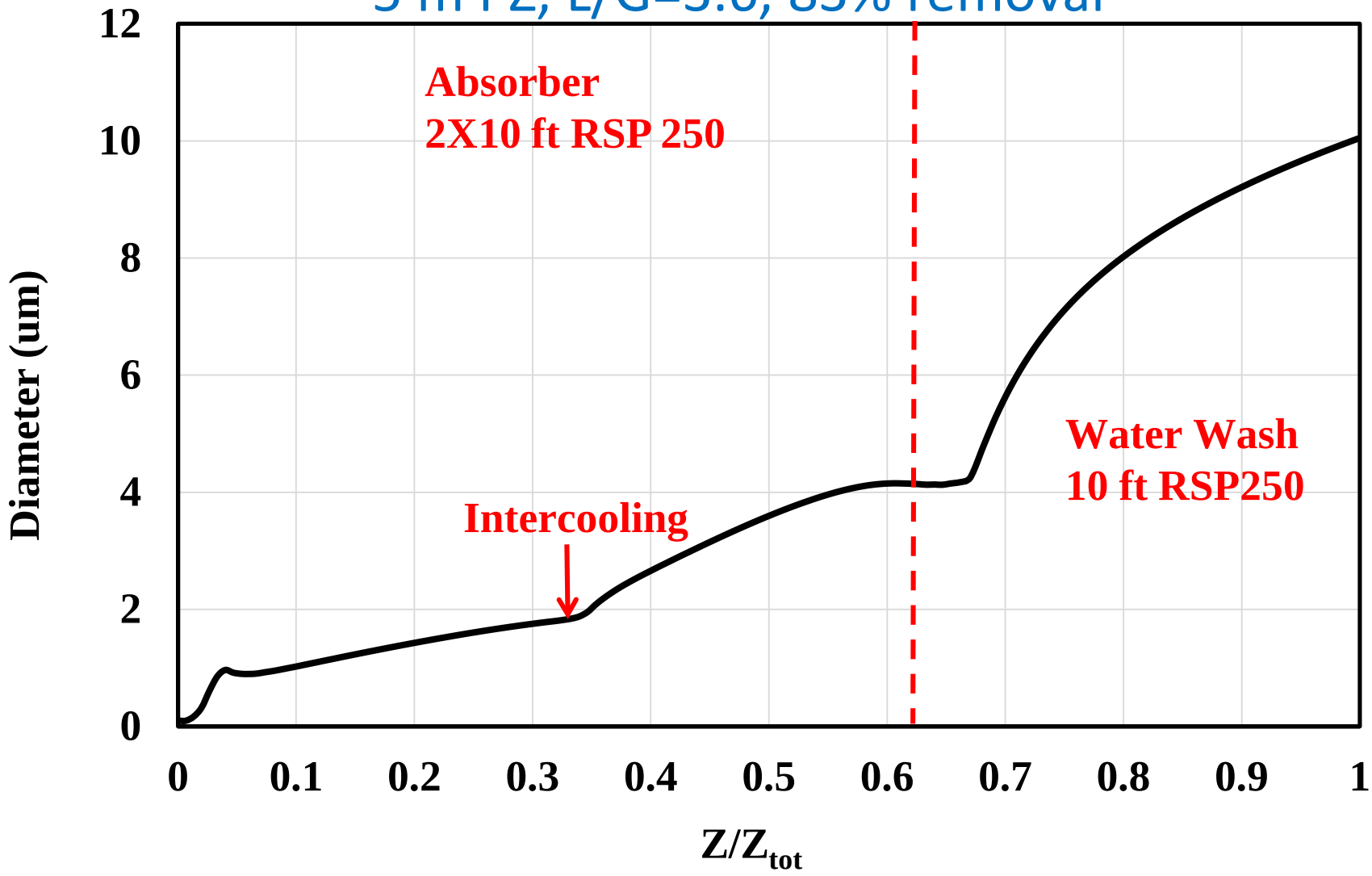
PZ can be used w/o solid precipitation
On shutdown, drain to rich storage



Manage PZ aerosol by Grow and capture

Calculated Aerosol Growth for SRP run 1

5 m PZ, L/G=3.6, 83% removal



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
  - Manage aerosol and solids
- 5 m PZ with the AFS will reduce capital cost

- **Acknowledgement:** "This material is based on work supported in part by the Department of Energy under Award Number DE-FE0005654."

Amine Aerosols can be measured by FTIR and Phase Doppler Interferometer (PDI)