



Pilot plant results with PZAS at the National Carbon Capture Center 2023 campaign

UTCCS-7

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Outline

- Project objectives and approach
- Top conclusions from campaign
- Solvent oxidation sources/mitigation methods
- NCCC pilot oxidation data (2023)
 - Liquid sample data
 - Gas phase data/water wash testing
- Dissolved oxygen (DO) measurements
- Carbon bed operations
- Reclaiming
- Conclusions



Project objectives and approach

Develop technologies to mitigate amine oxidation due to presence of O_2 and NO_2 in flue gas.

- Test solvent oxidation mitigation methods in lab
- Pilot test mitigation approaches at UT SRP (0.1 MW_e) & National Carbon Capture Center, Wilsonville, AL (1 MW_e)
- Perform economic analysis of oxidation mitigation strategies



Top conclusions from this work

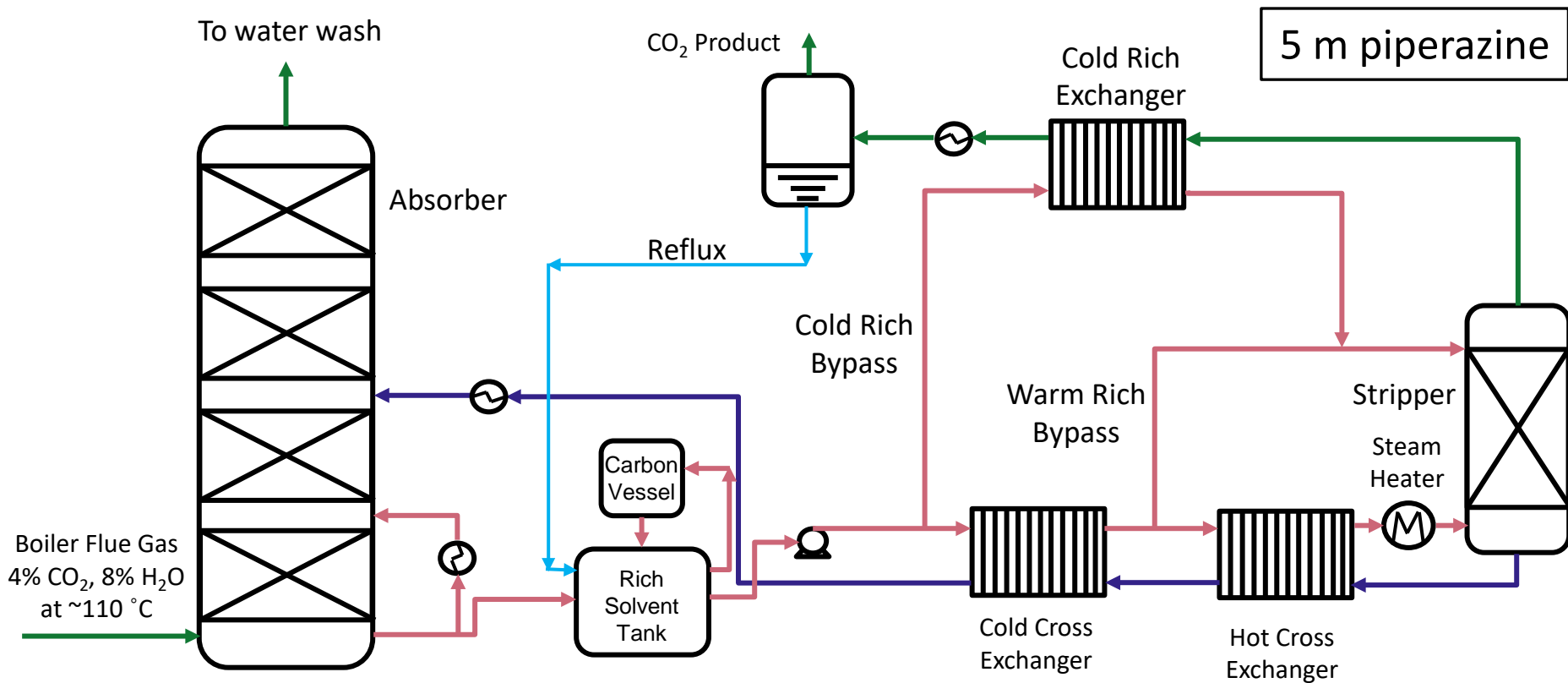
- Completed 5,900 hours of run-time w/ oxidation mitigation methods + reclaiming
- DO measurements demonstrated:
 - N_2 sparging in abs sump removed >75% DO
 - DO will be a good online tool for monitoring solvent health in real-time
- Carbon bed
 - May have experienced breakthrough
 - Two possible corrosion events occurred
 - GAC may have behaved as an oxidation catalyst bed
- Amino acids amounted to ~65 mmols/kg (EDA 40 mmols/kg) at 4,180 hours
- Solvent reached “tipping point” ~4,300 hours - NH_3 in abs outlet gas and online DO measurements
- Single stage thermal reclaiming reversed DO/ NH_3 trends; removed >95% of diss. metal ions
- Acid wash reduced NH_3 in water wash outlet to ~50 ppb
- Measured an overall solvent make-up rate of 0.5 kg PZ/tonne CO_2



Oxidation sources of interest

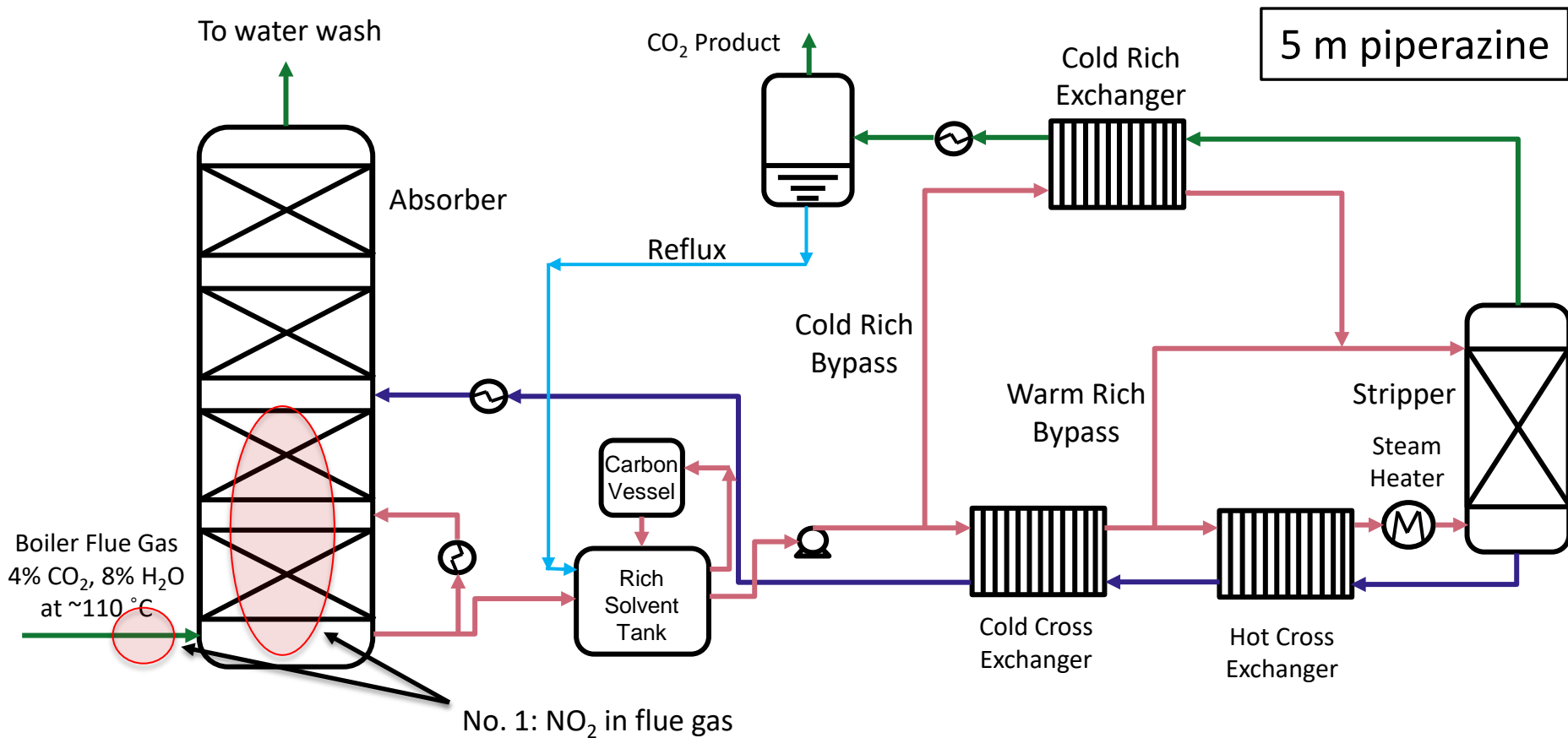


PZAS™ process flowsheet



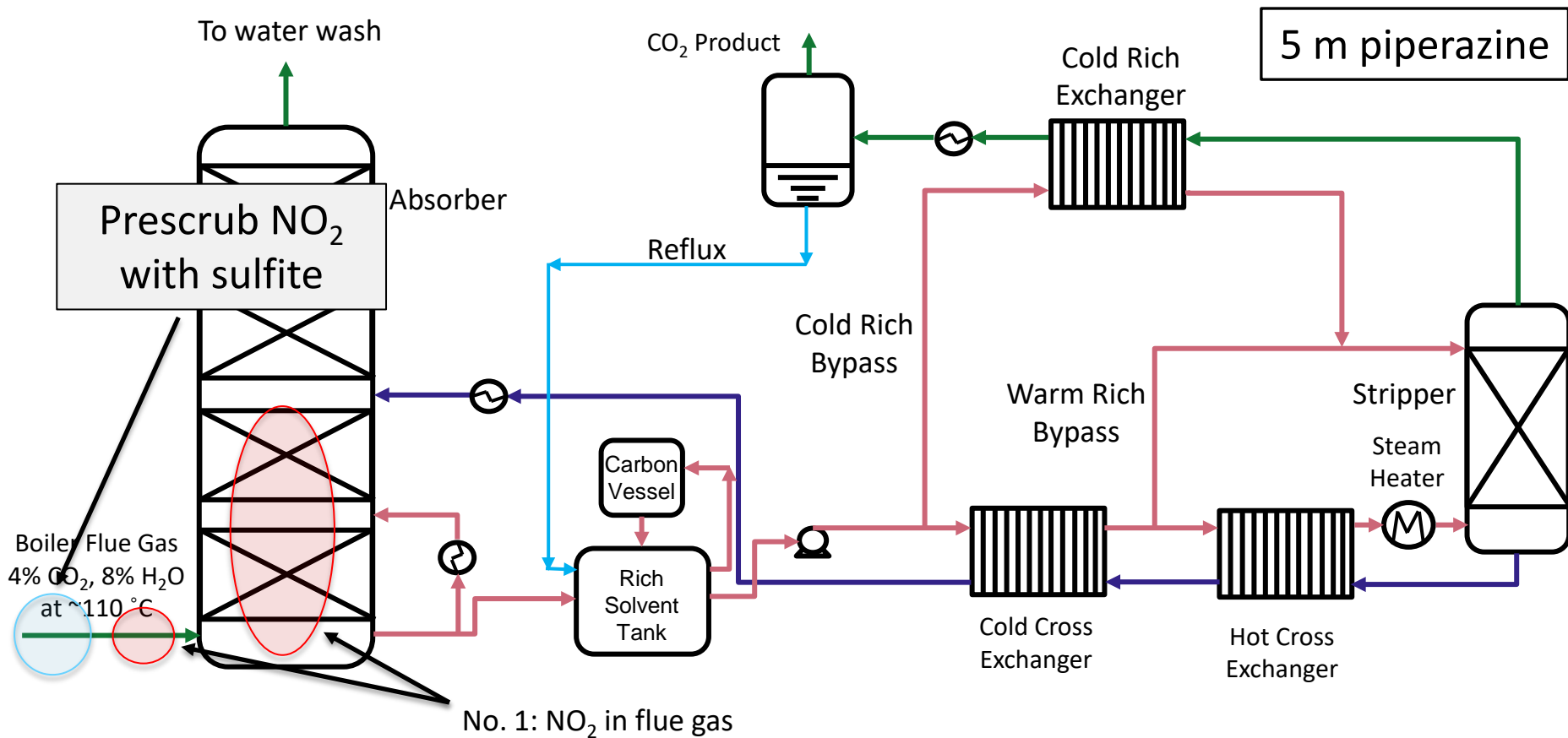


PZAS™ process flowsheet



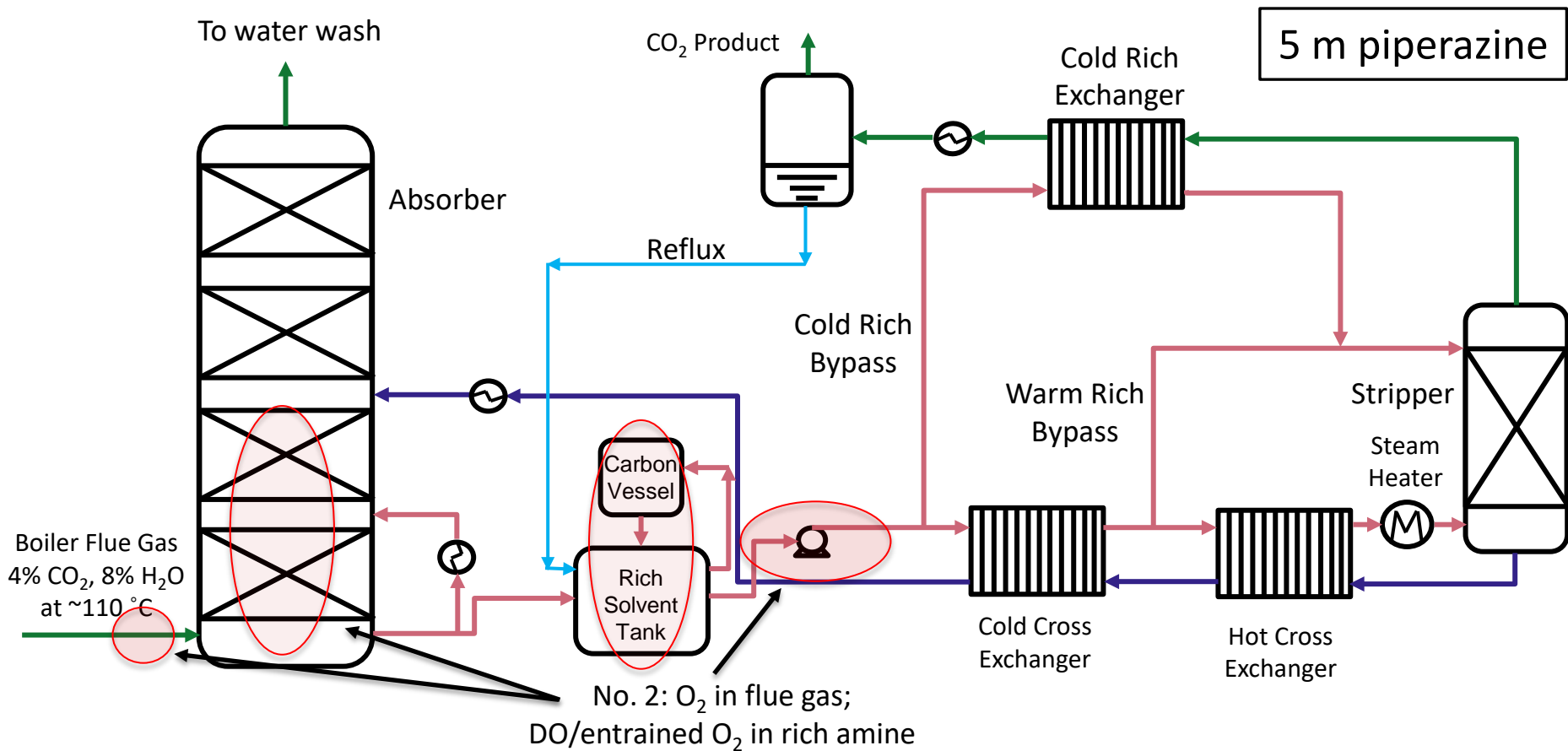


PZAS™ process flowsheet



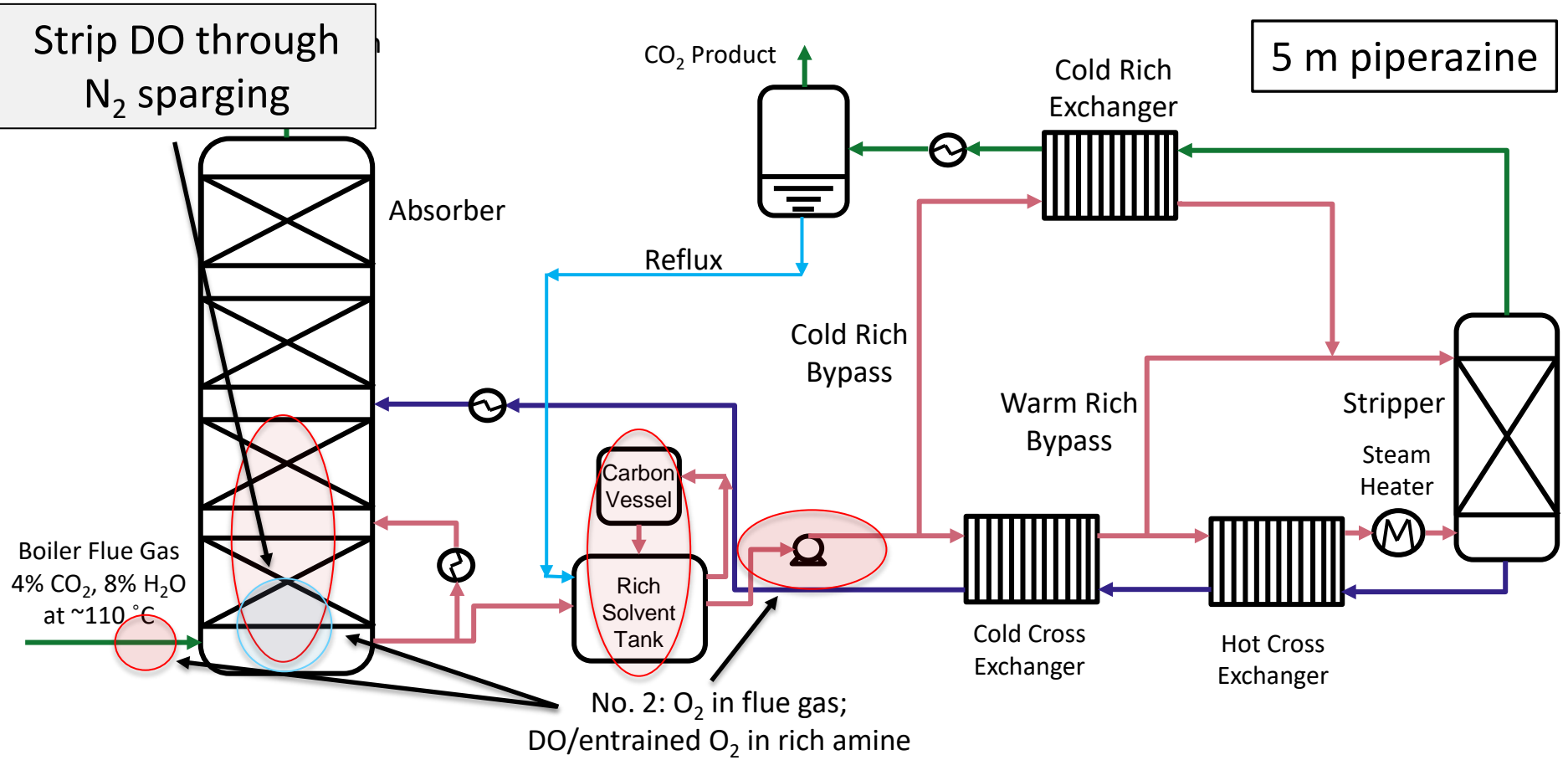


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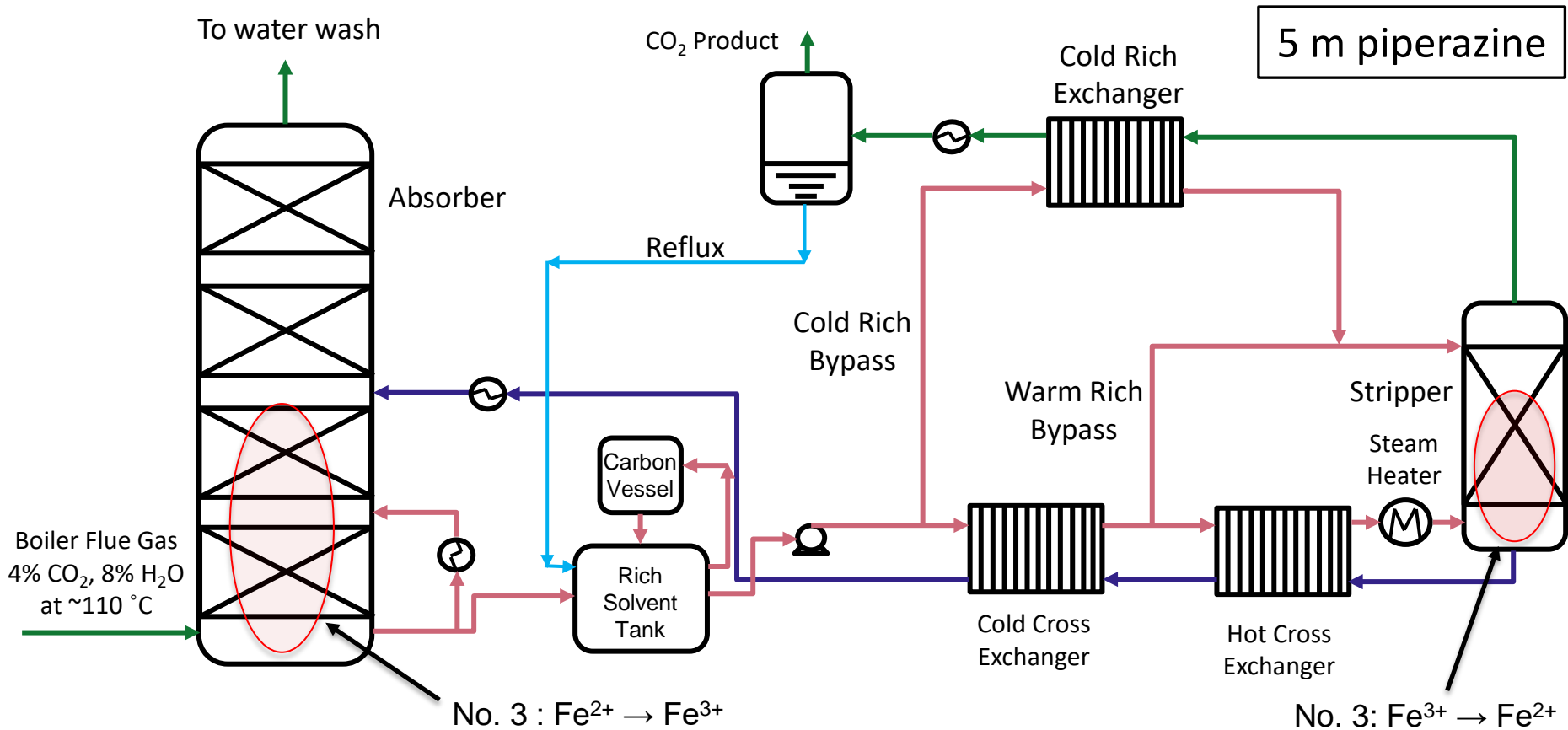


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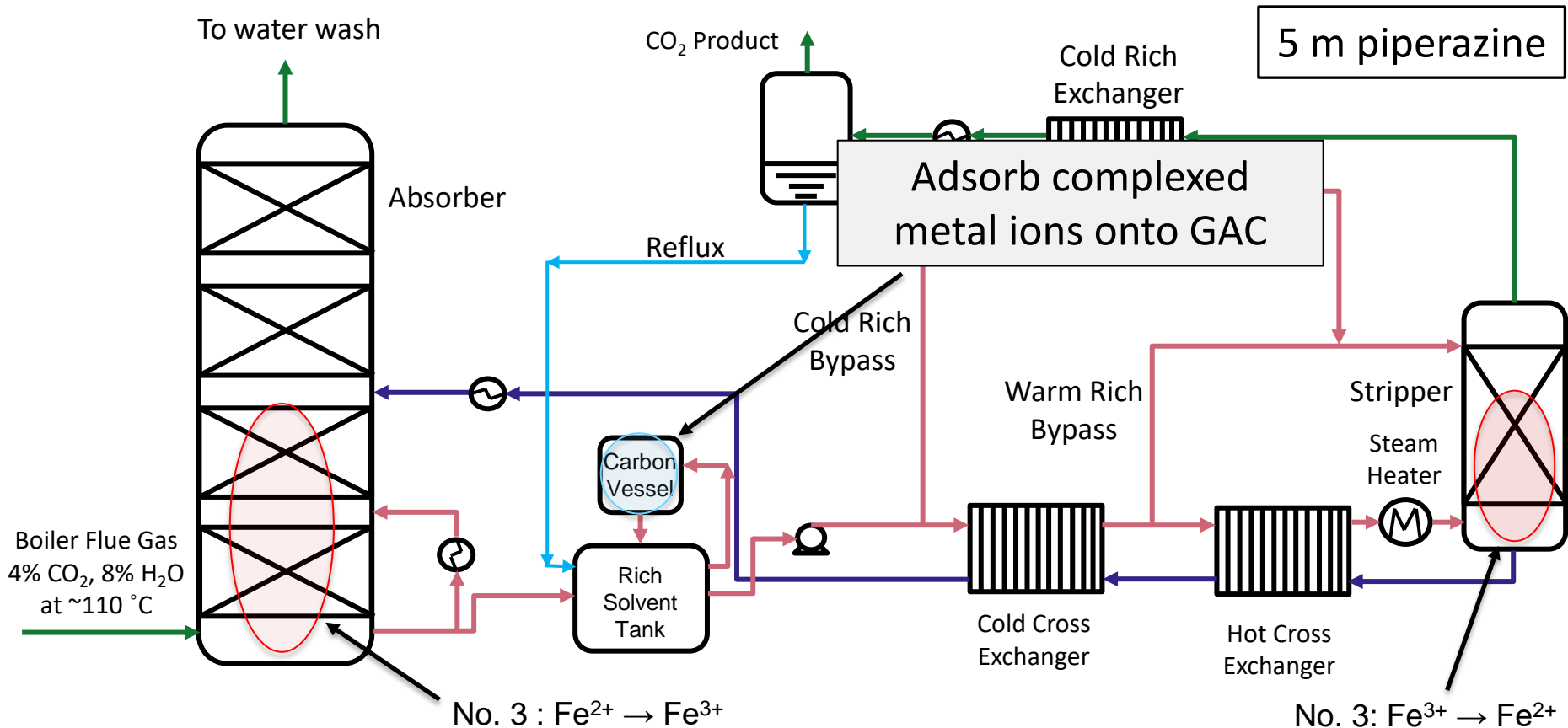


PZAS™ process flowsheet





PZAS™ process flowsheet





NCCC campaign overview



NCCC pilot plant

Parameter	NCCC (Southern Co.)
Size equivalent (MW_{eq})	1.0
Solvent inventory (gal)	1500
Abs packing height (feet)	40
Flue gas source	Natural gas boiler
Flue gas rate (lb/hr)	8,000 (~2,000 SCFM)
CO ₂ capture rate (MT/d)	6

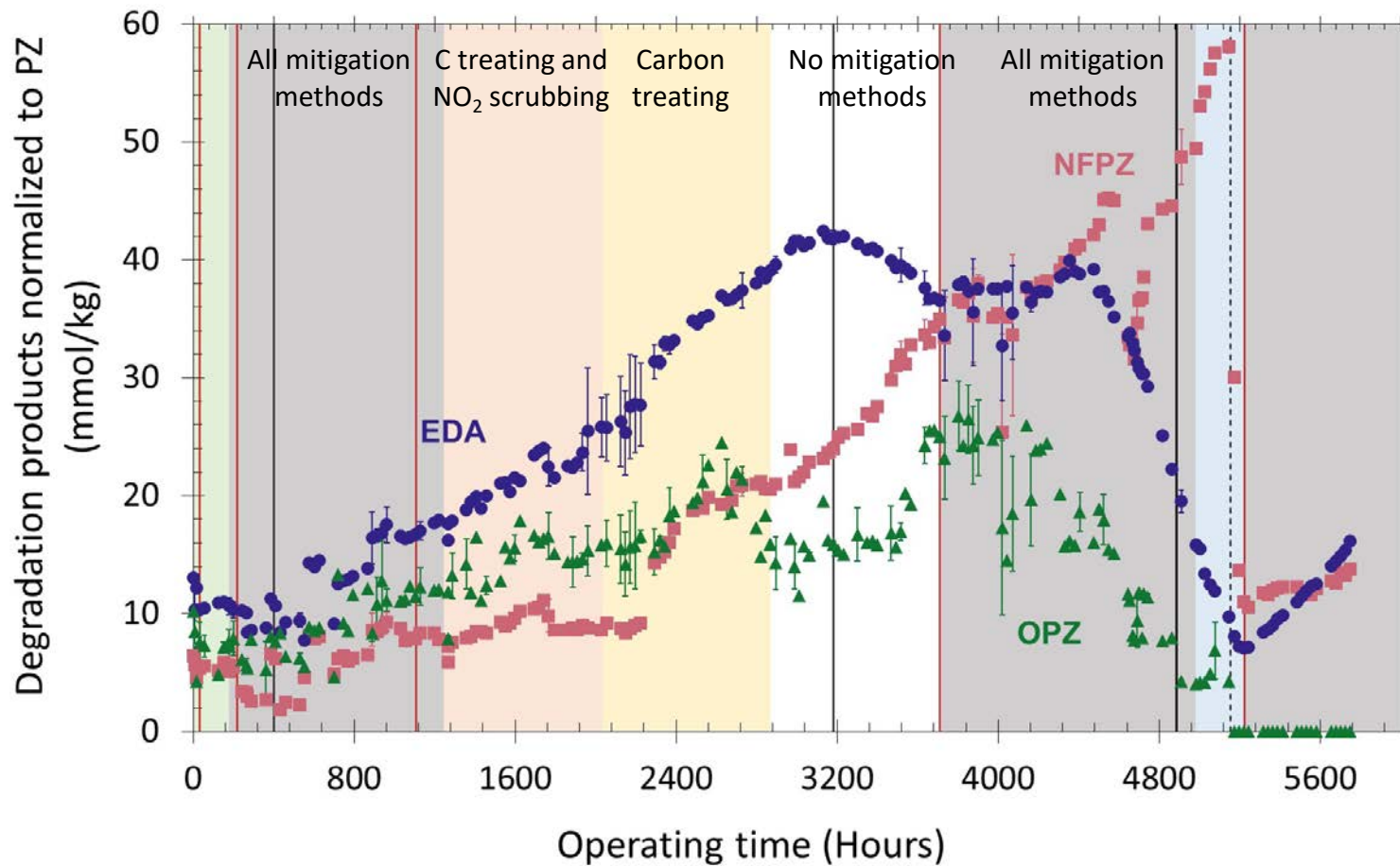


Degradation data (2023)

- (1) Liquid phase**
- (2) Gas phase**

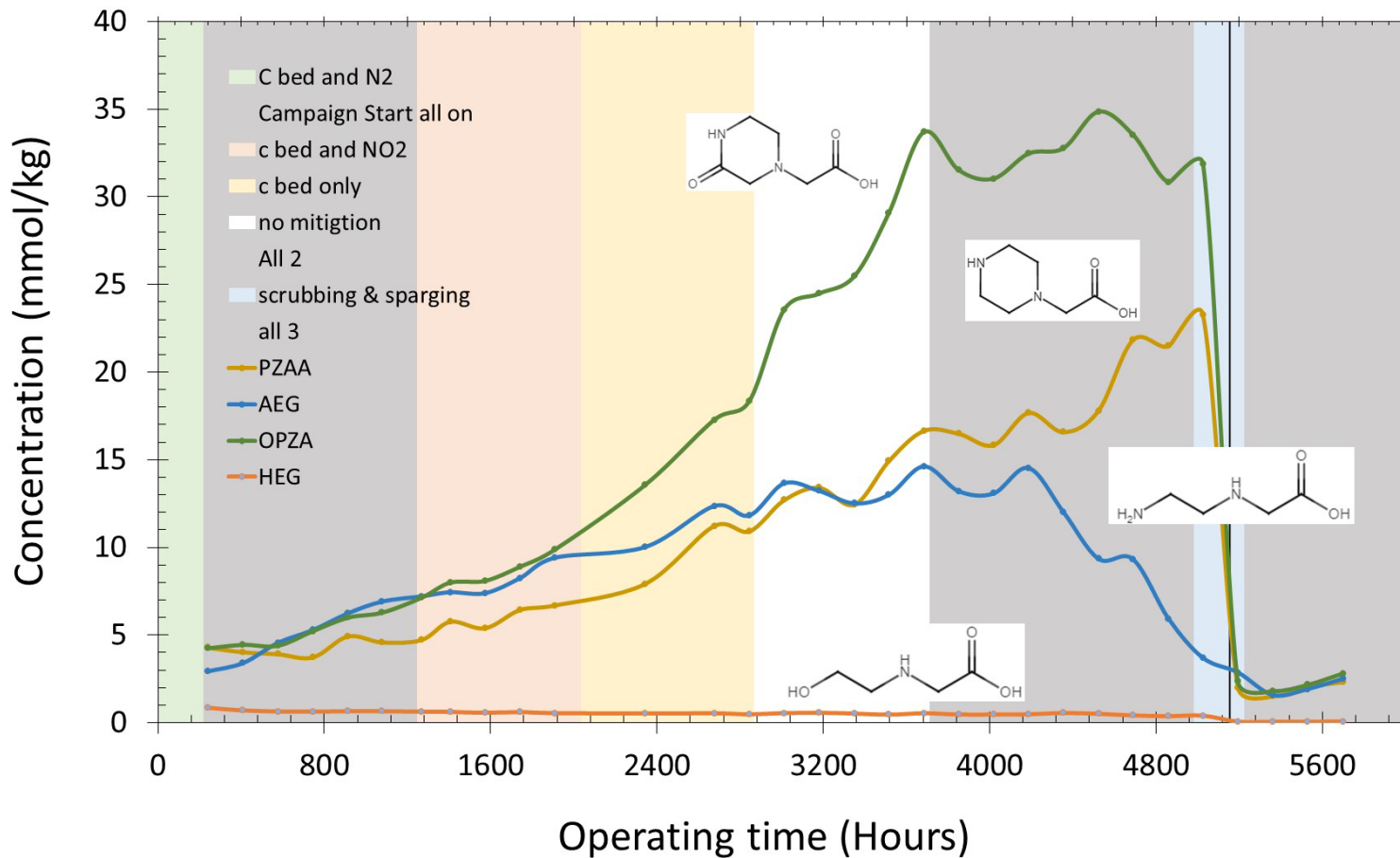


Degradation products by cation IC at NCCC (2023)



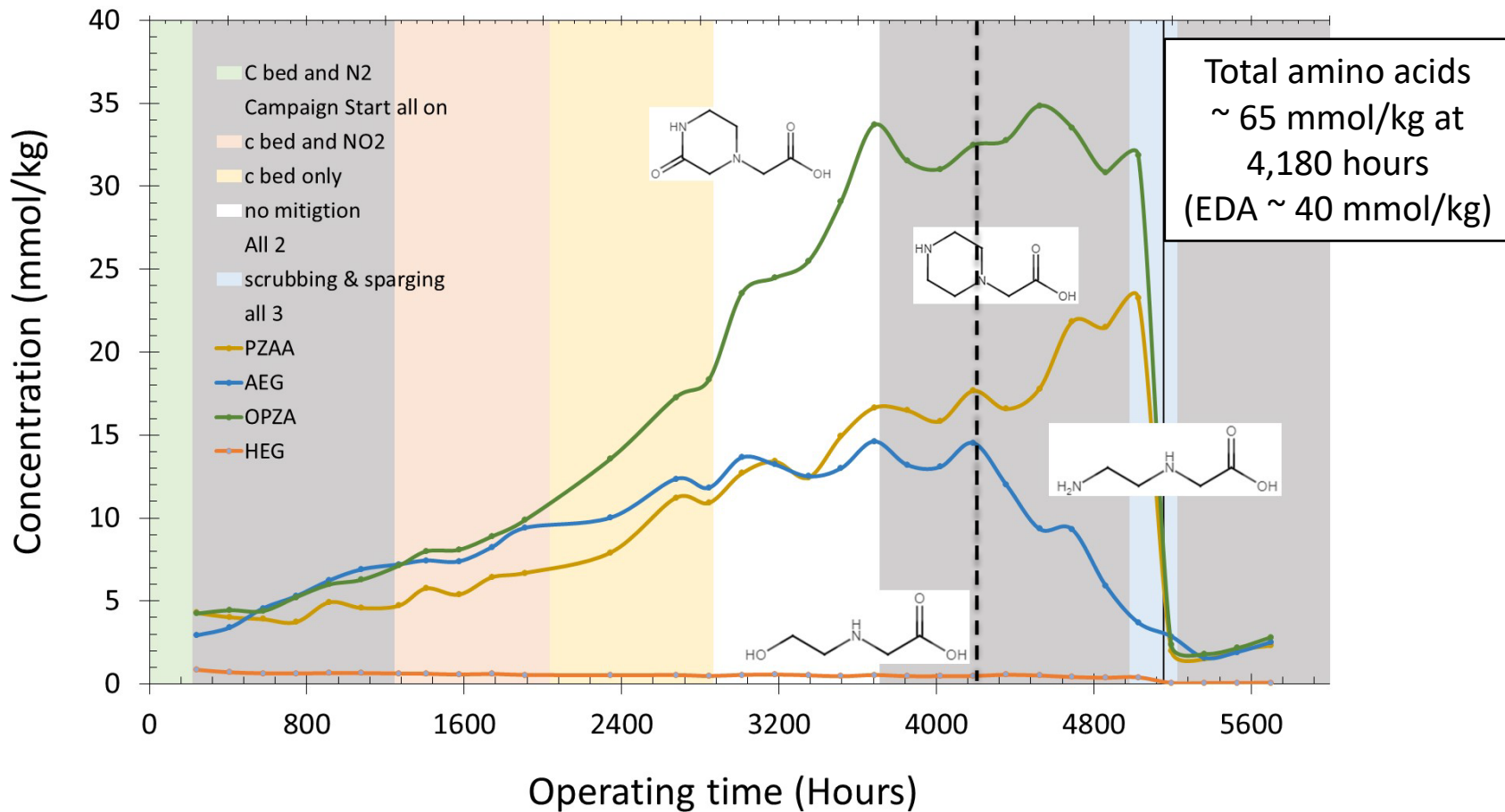


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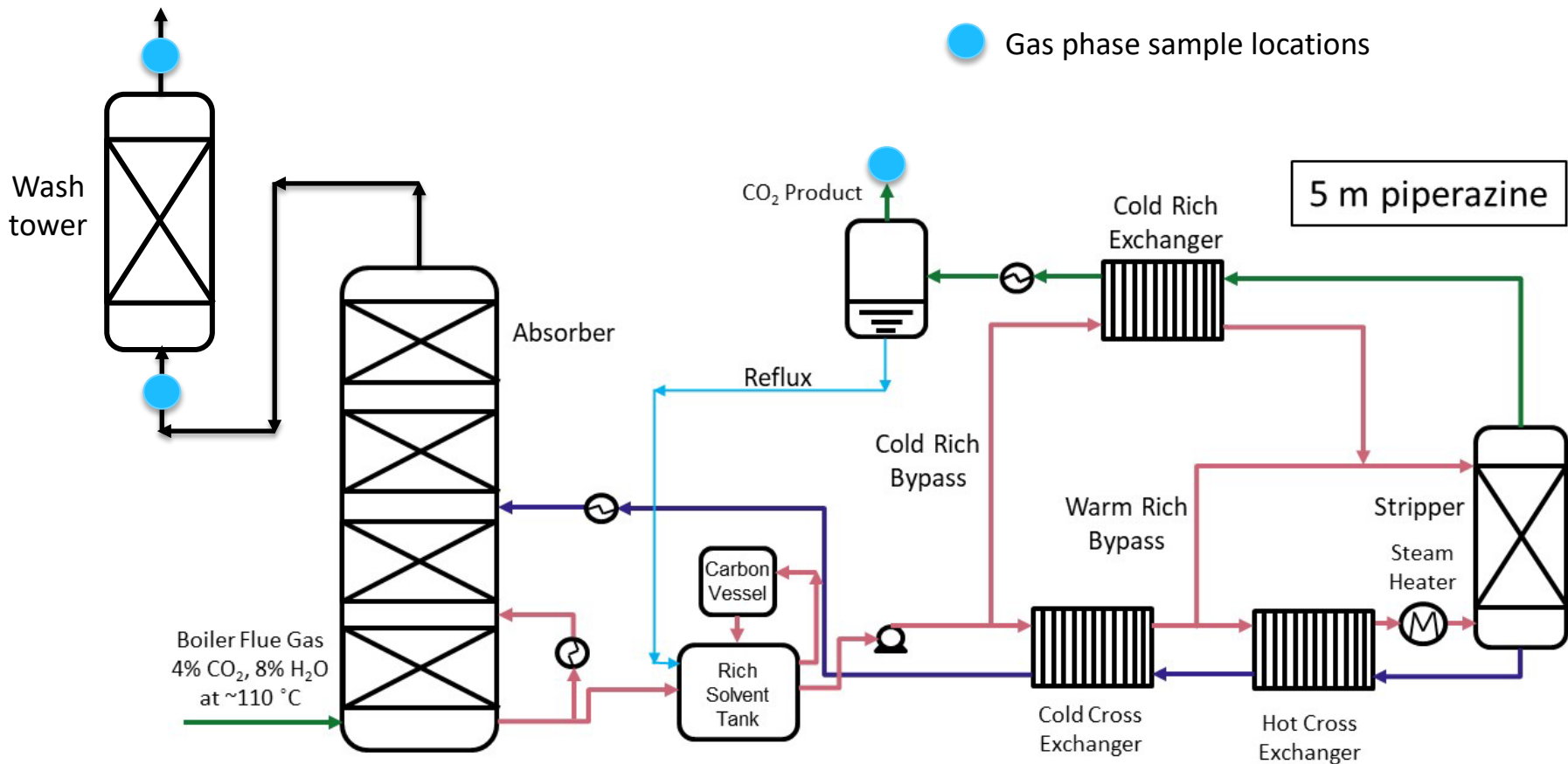




Gas phase monitoring data (2023)

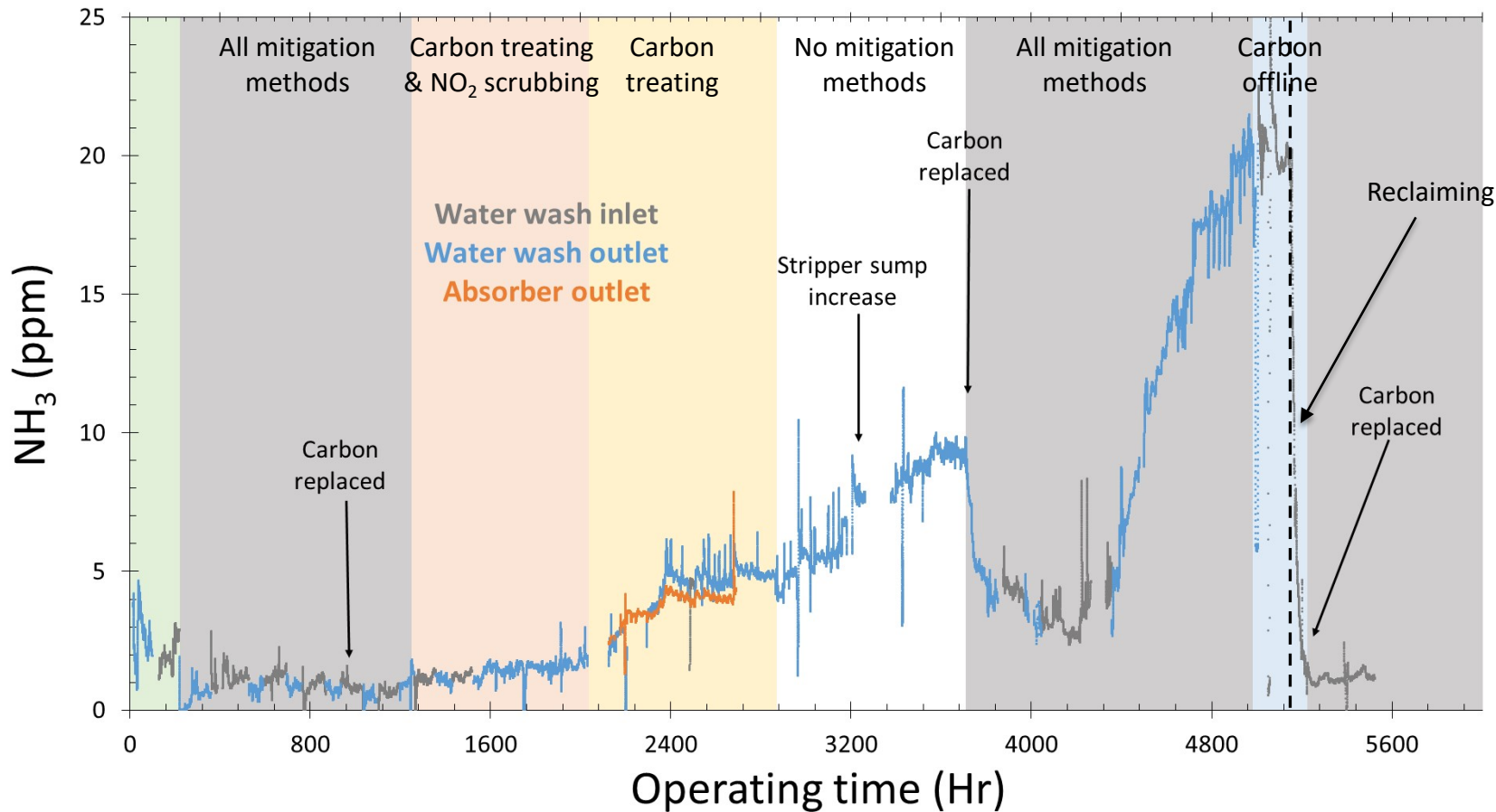


Gas phase monitoring locations (FTIR)





Flue gas monitoring data (FTIR)

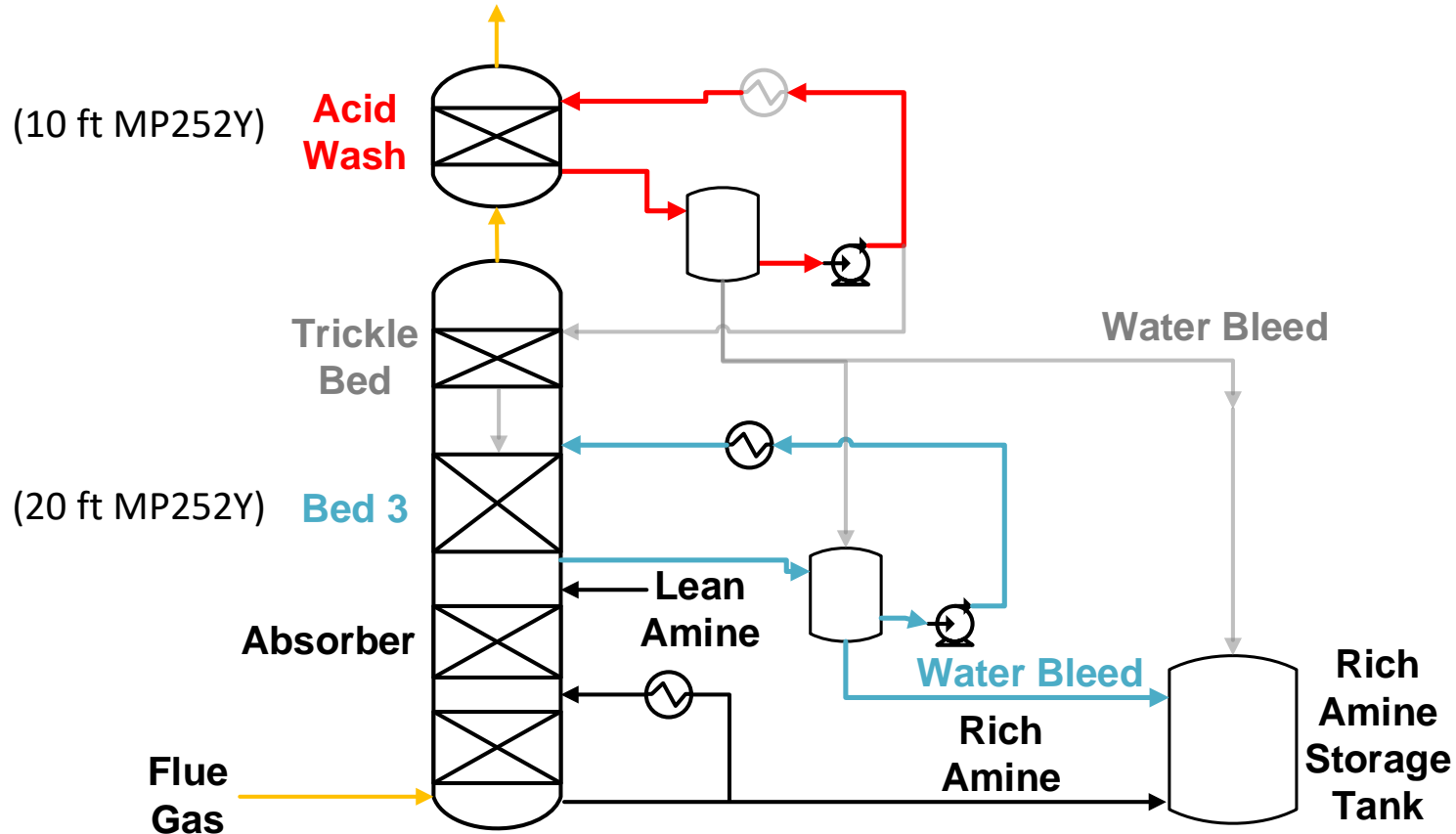




Water wash testing

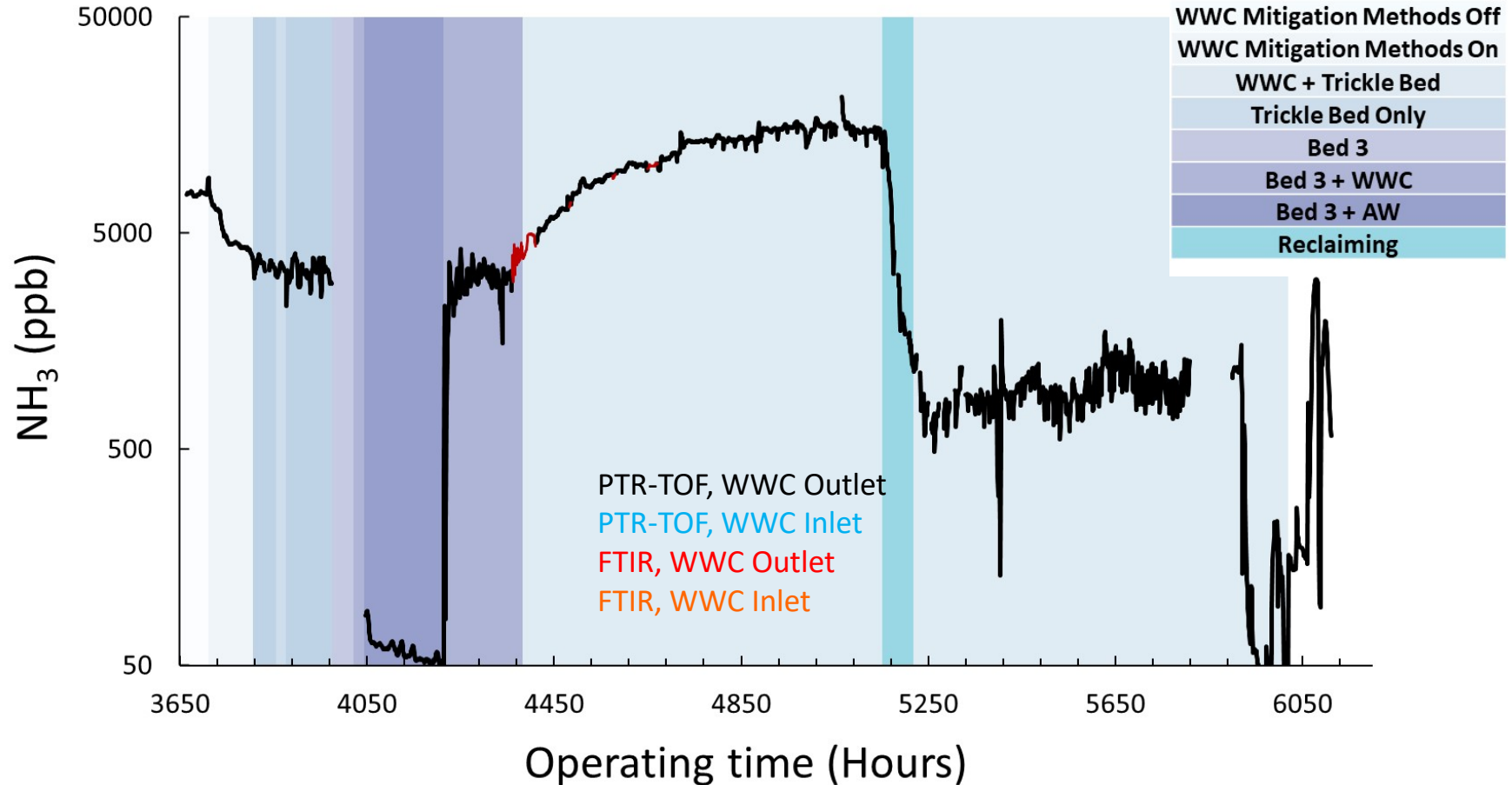


Bed 3 + wash column acid wash





PTR-TOF-MS data – NCCC (2023)





PTR-TOF-MS data – WW outlet

Op. time (Hours)	Water wash Operation	NH₃ (ppb)	PZ (ppb)	Acetaldehyde (ppb)
3690	Conventional	7,443 (8,795)	219 (494)	34.4 (1,034)
3880	Trickle bed	3,470	1.1	51.4
4210	Bed 3 + acid wash	51	0.1	34.2
4340	Bed 3 + WWC	2,445	0.1	24.6
5700	Conventional (post reclaiming)	1,150	0.3	38.9

Data in () measured with FTIR.
Reclaiming conducted 9/18 – 9/21.



PTR-TOF-MS data – WW outlet

Op. time (Hours)	Water wash Operation	Good agreement	Bad agreement	
		NH ₃ (ppb)	PZ (ppb)	Acetaldehyde (ppb)
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PTR-TOF-MS data – WW outlet

Unaffected but low 

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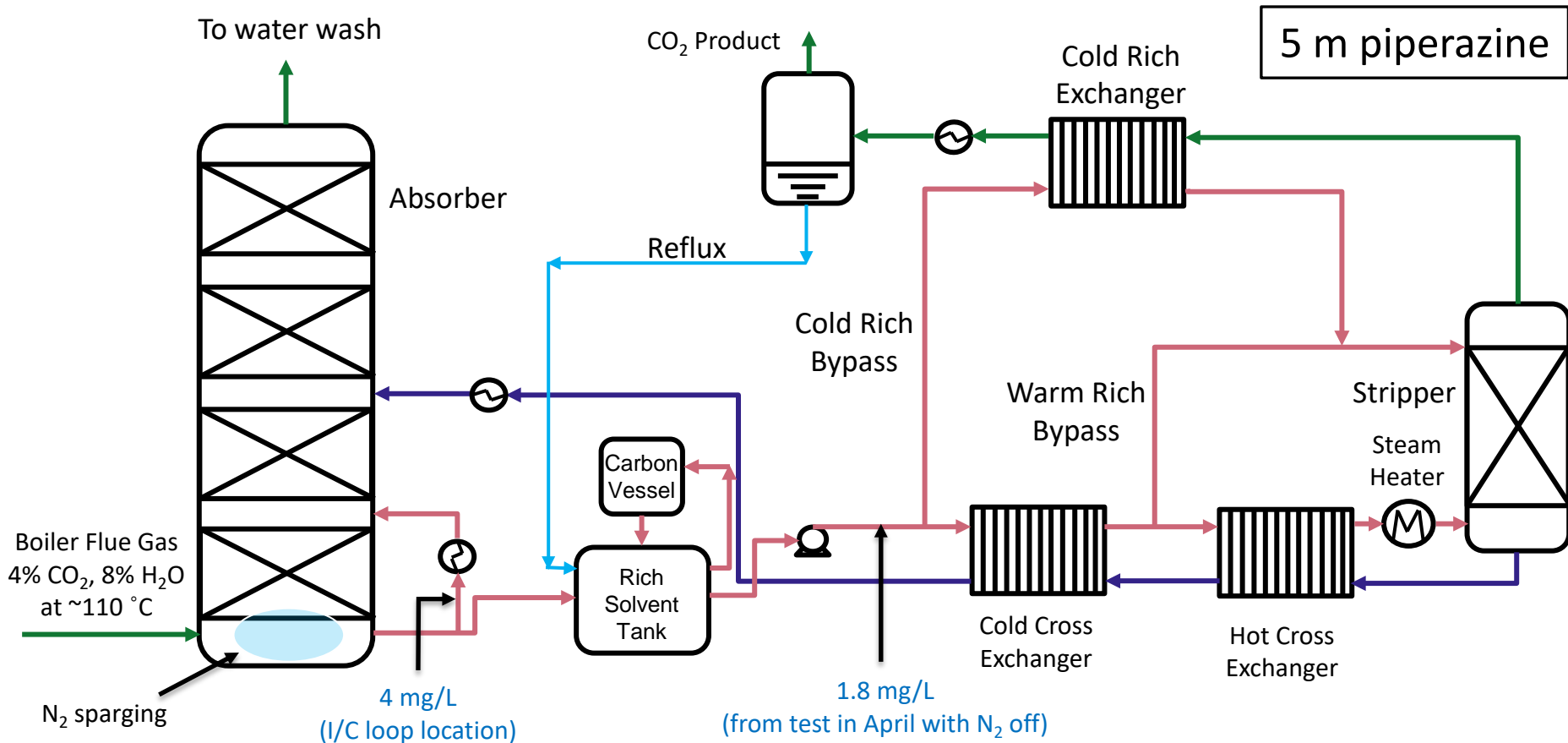
Data in () measured with FTIR.
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Dissolved oxygen measurements

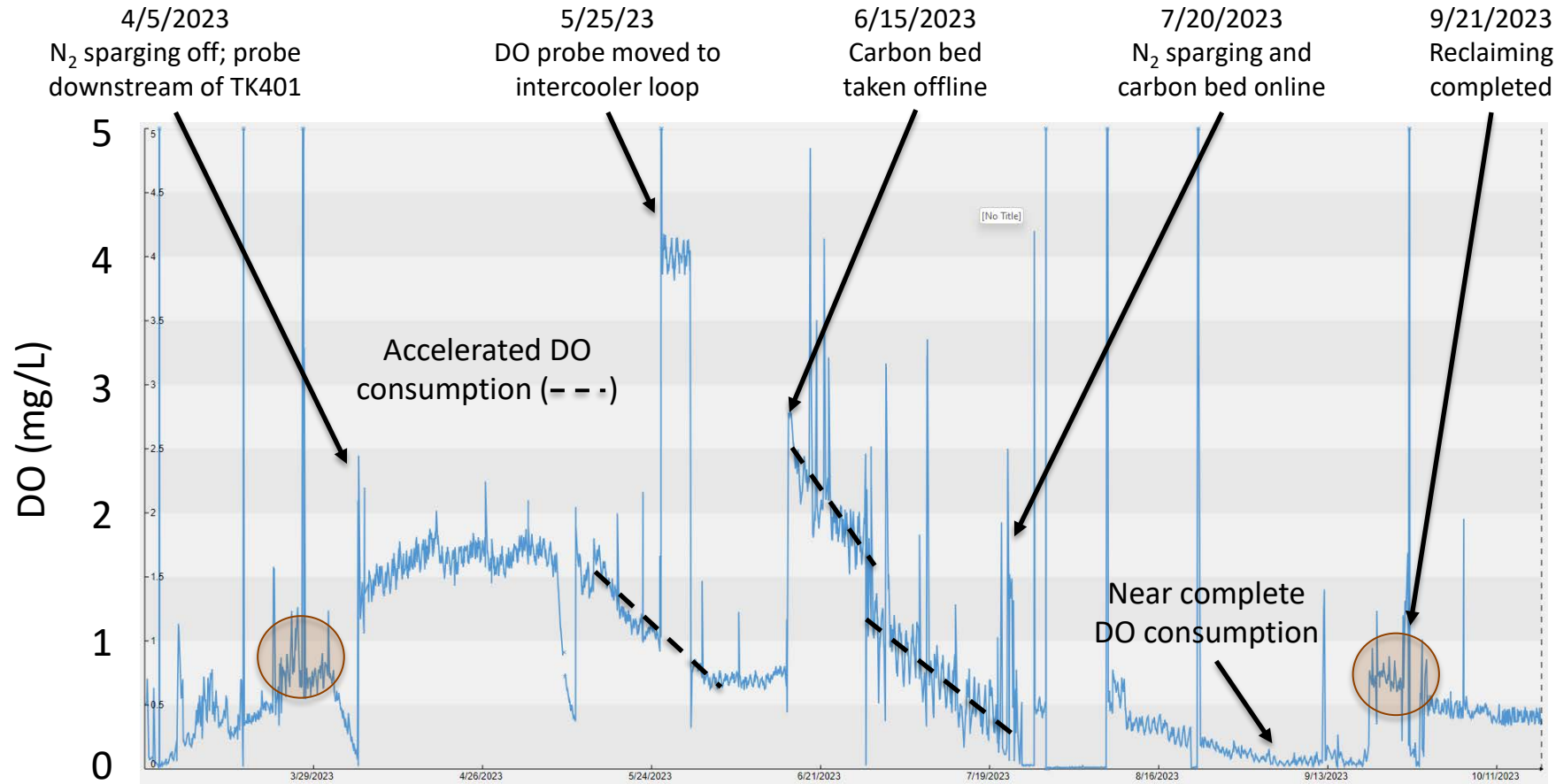


PZAS™ process flowsheet



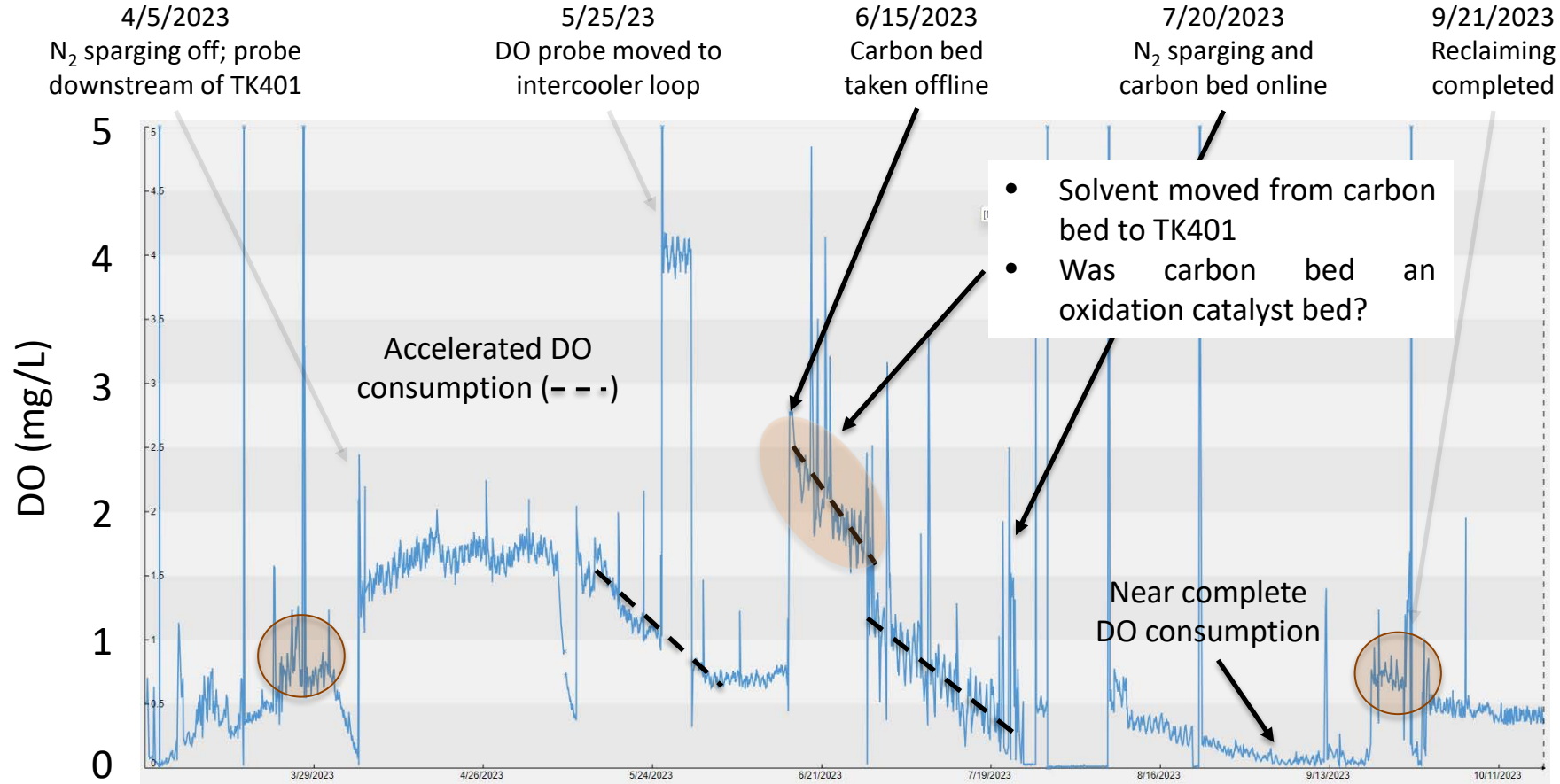


DO probe measurements





DO probe measurements





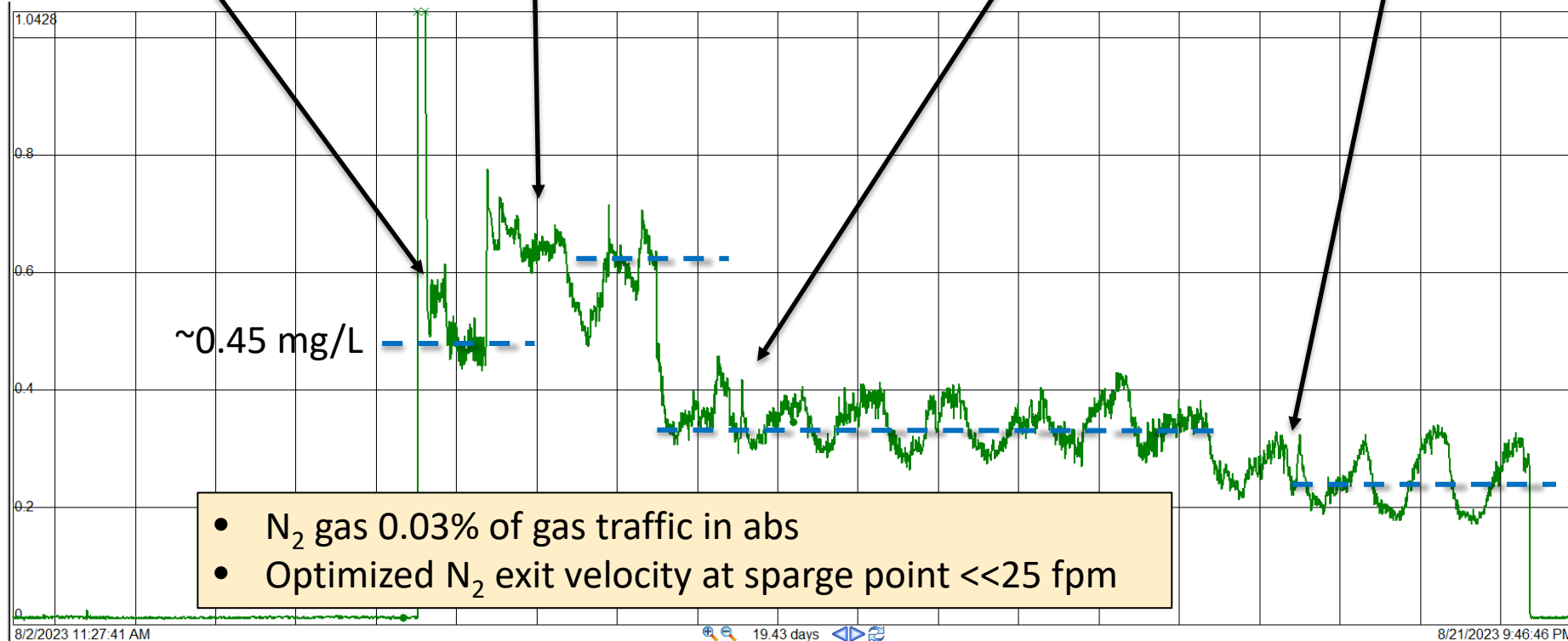
DO probe readings with N₂ sparging on

DO probe moved to I/C
loop, N₂ at 2 SCFM

N₂ gas sparging at
4 SCFM

N₂ gas sparging at
1 SCFM

N₂ gas sparging at
0.5 SCFM

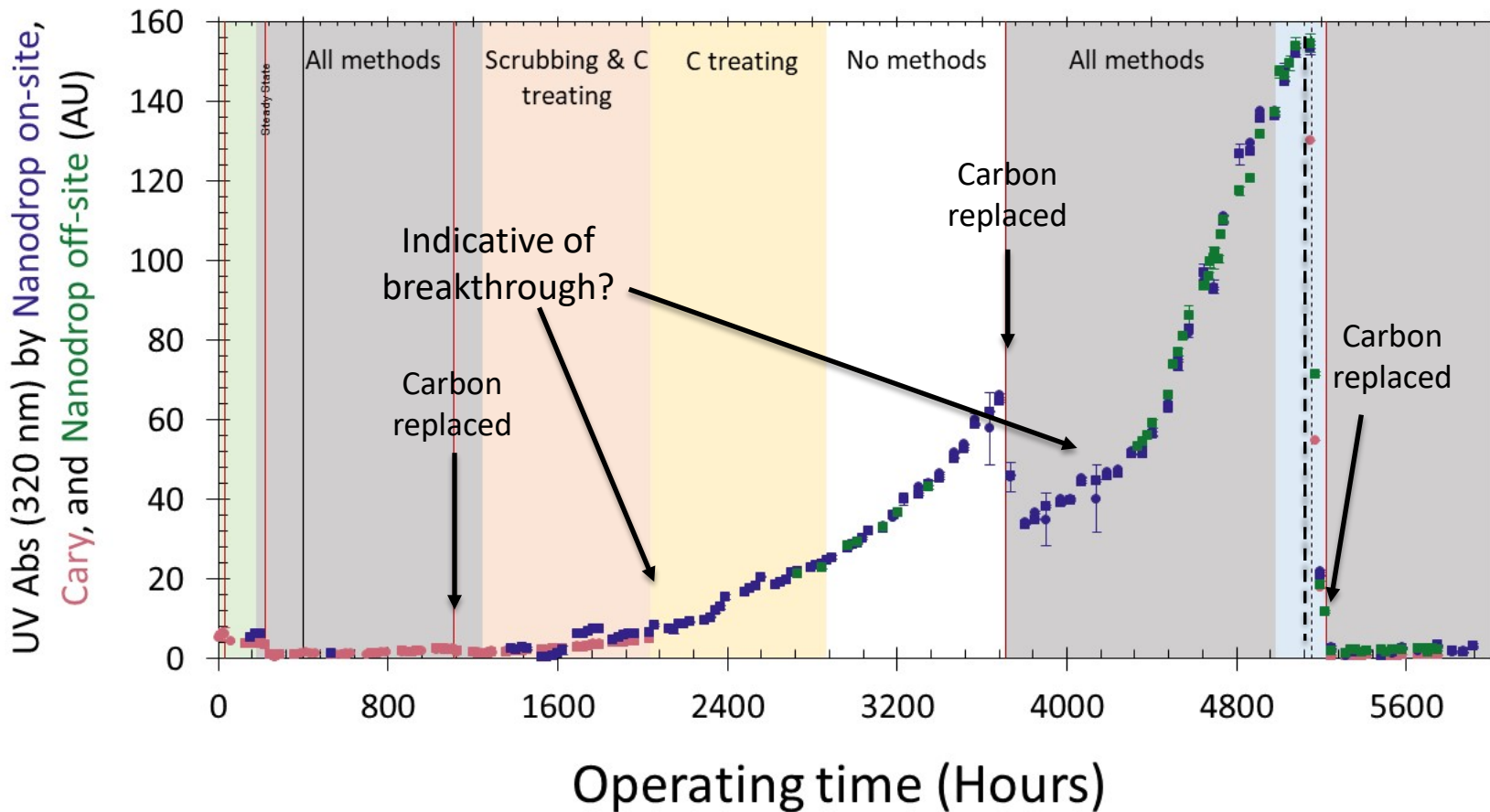




Carbon bed operations

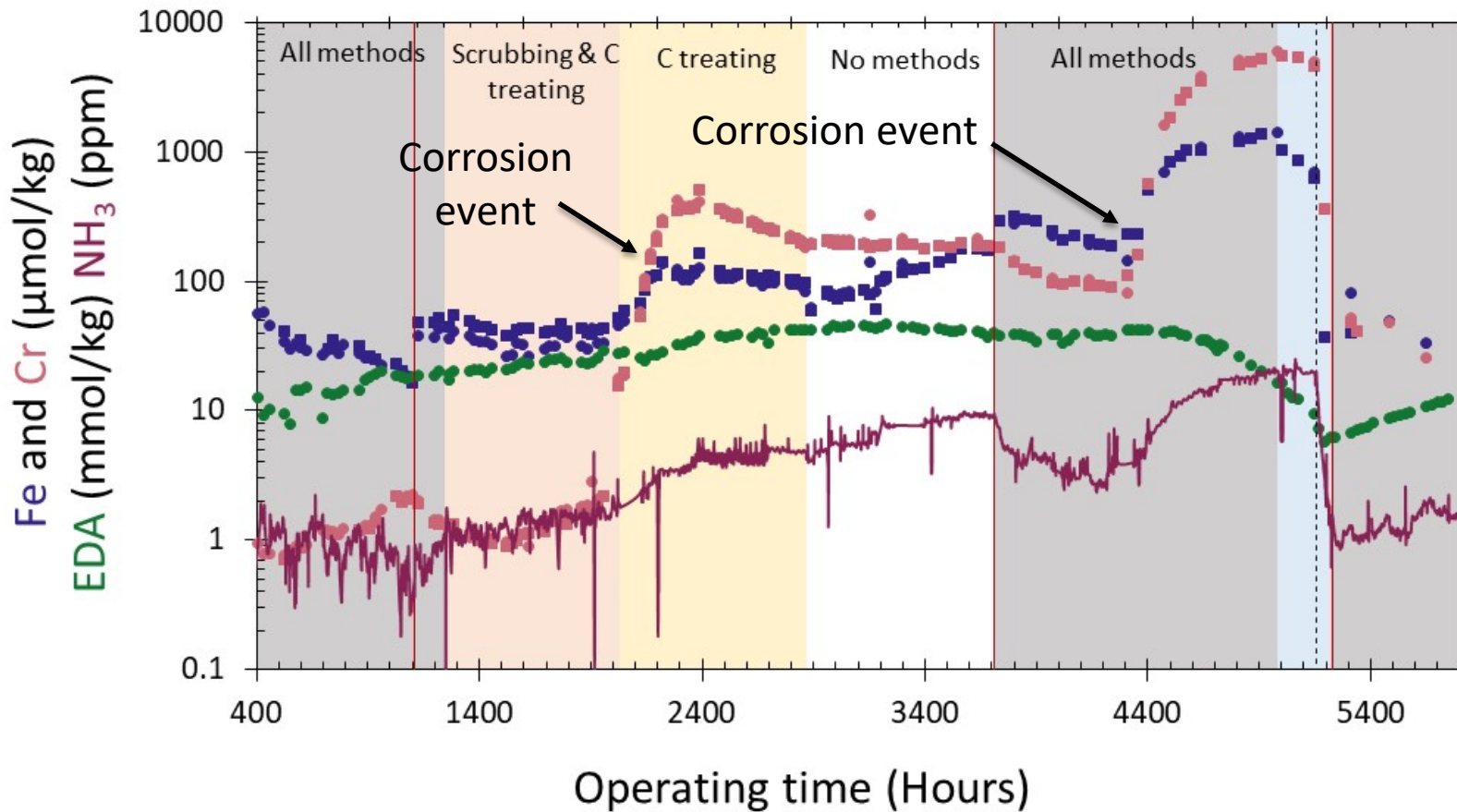


UV-Vis absorbance at NCCC (2023)





Various species at NCCC (2023)





Solvent reclaiming



CCR solvent reclaiming (Sept. 18 – 21)

- Semi-batch thermal reclaiming
- Processed ~4,187 gallons of solvent (3X inventories)
- Pulled from lean amine at ~1.1 gpm; returned to rich amine tank
- Solvent loss ~300 gallons (~32% of inventory; CCR predicted 5 - 7%)

Before – 9/18



Product from
CCR unit

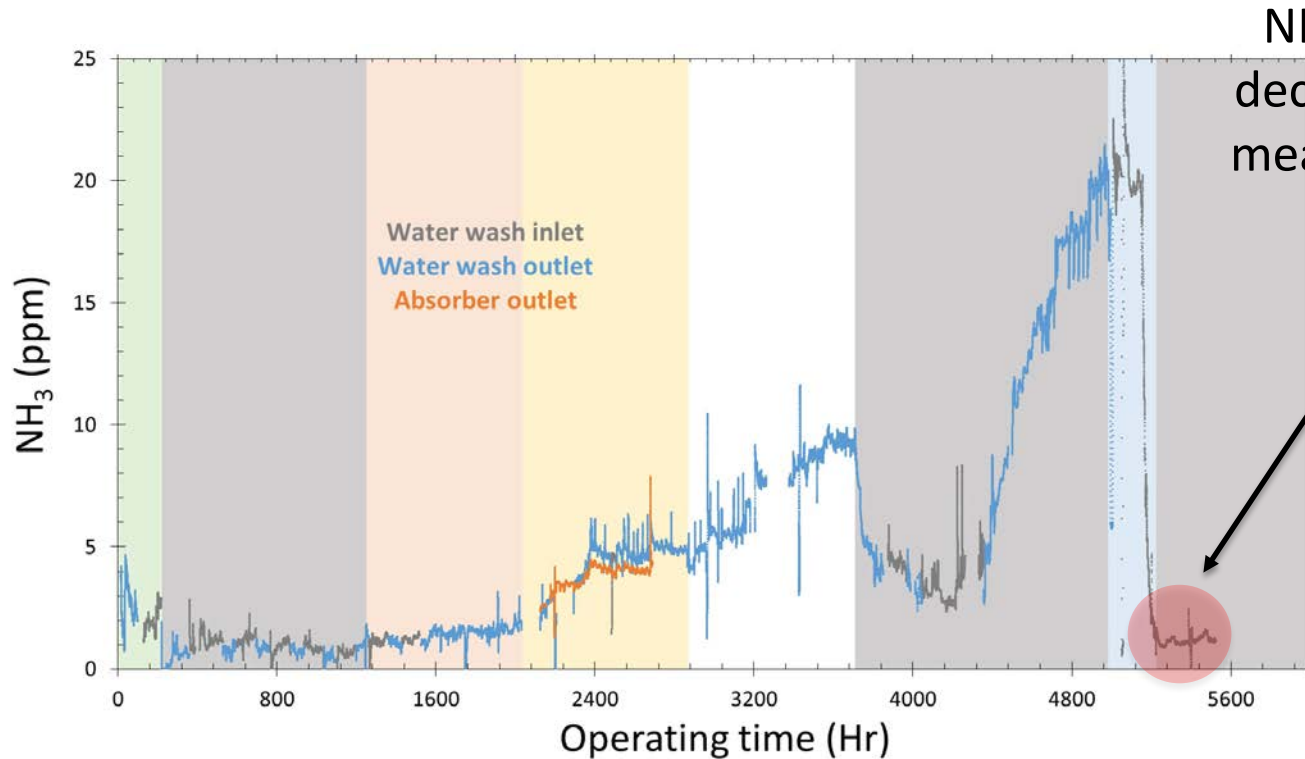


After – 9/21





CCR solvent reclaiming (Sept. 18 – 21)



NH_3 concentrations (FTIR) decreased to concentrations measured early in campaign.



Conclusions

- Completed 5,900 hours of run-time w/ oxidation mitigation methods + reclaiming
- DO measurements demonstrated:
 - N_2 sparging in abs sump removed >75% DO
 - DO will be a good online tool for monitoring solvent health in real-time
- Carbon bed
 - May have experienced breakthrough
 - Two possible corrosion events occurred
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- Measured an overall solvent make-up rate of 0.5 kg PZ/tonne CO_2



Project participants

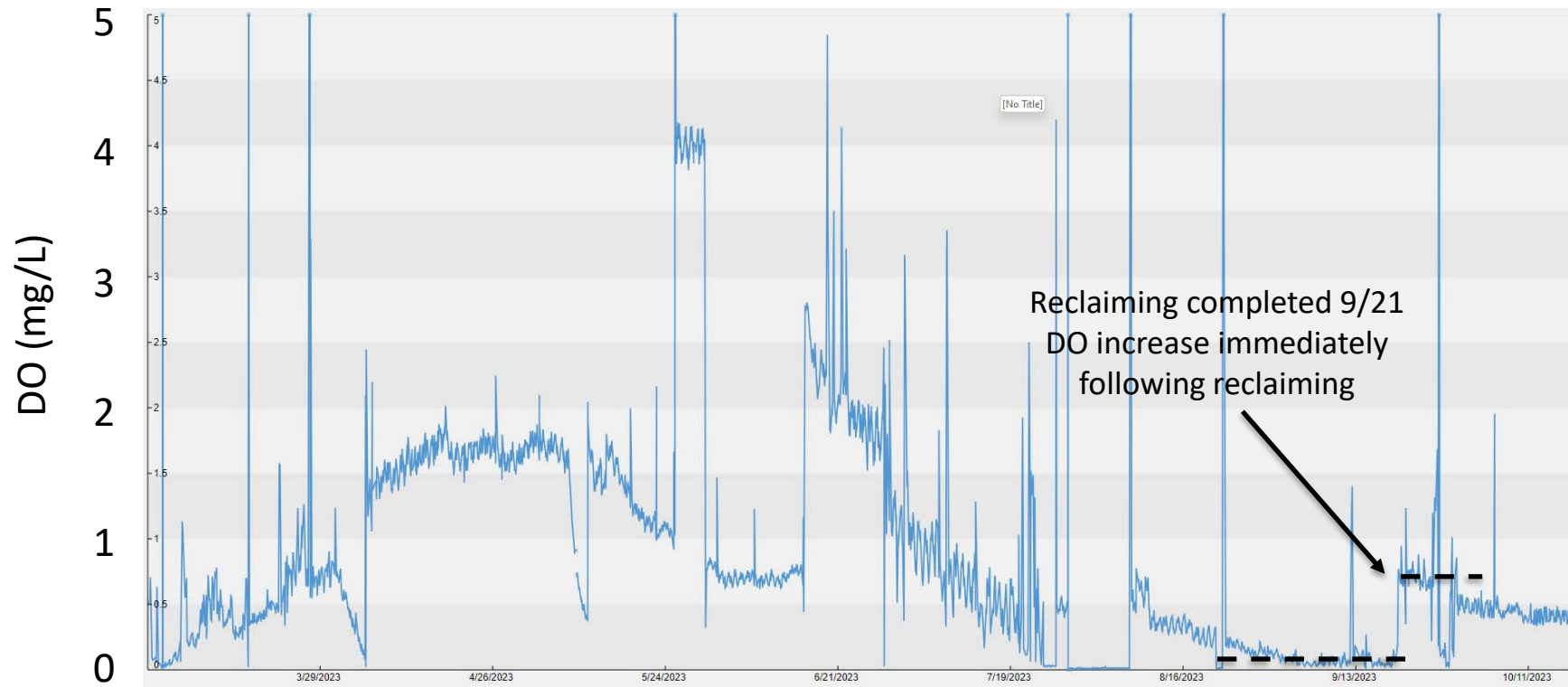
Party	Person	Role
NETL	Krista Hill	Project Manager
UT-Austin	Dr. Gary Rochelle Dr. Fred Closmann	Principal Investigator Project Manager
GRAs	Chih-I Chen Ariel Plantz Miguel Abreu Athreya Suresh Ben Drewry	HGF - NO ₂ studies Iron studies Pilot support Pilot support Flue gas stream measurements
SRP Staff	Dr. Frank Seibert JR Campos	Director SRP Operations technician
Honeywell	Carl Stevens Nathan Lozanoski Jeff Tyska	Technology development
NCCC	NCCC Team	Pilot implementation



Questions?

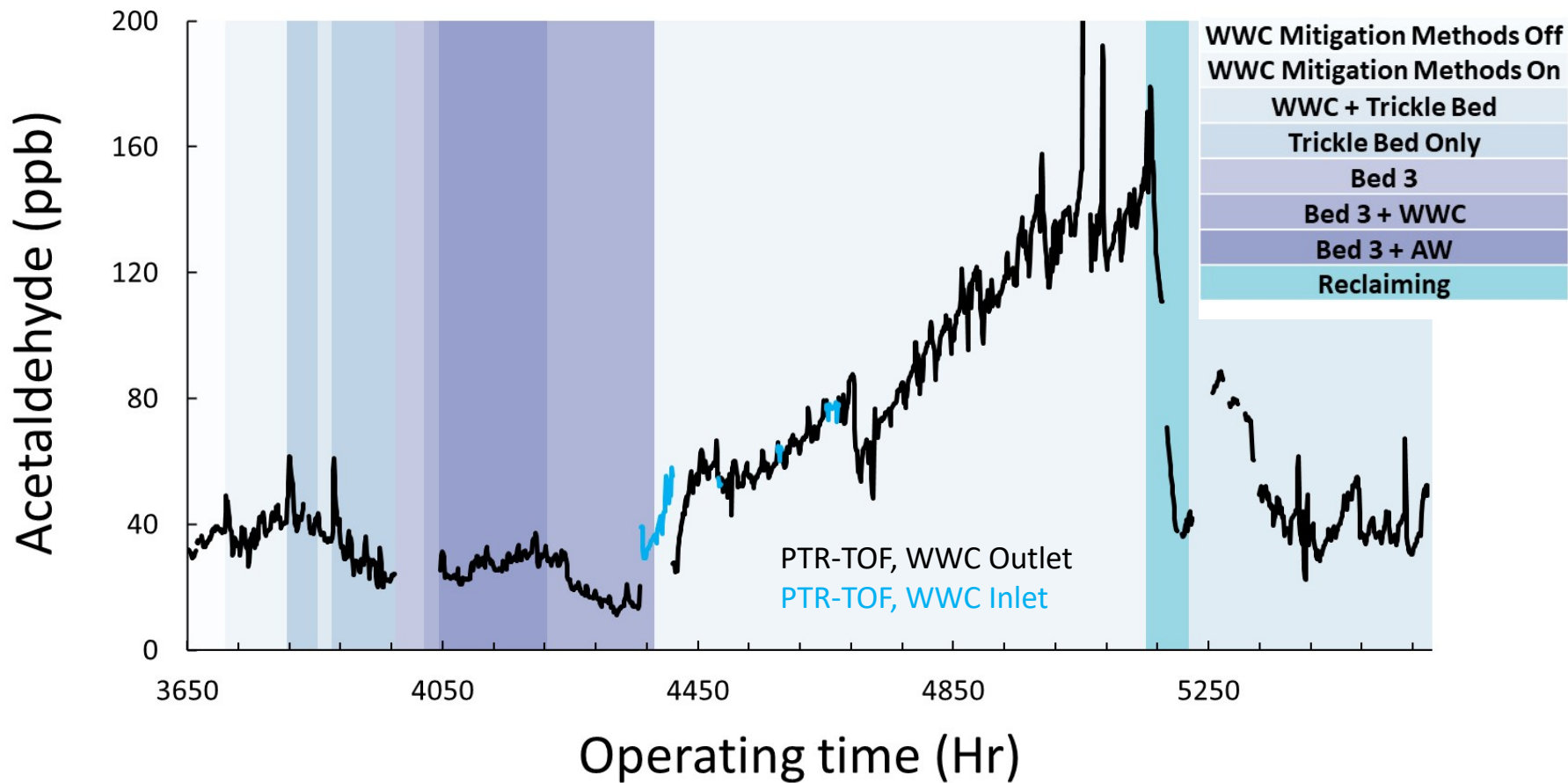


DO probe measurements





PTR-TOF-MS data – NCCC (2023)





Solvent make-up rates

Solvent	Rate (kg/MT CO ₂)	Flue gas	CO ₂ (%)	O ₂ (%)	NO _x /NO ₂	Facility	Author
CASTOR1, CASTOR 2	1.4	coal	12	NA	<65 ppm NO _x	Esbjergvaerket, Denmark	Knudsen, 2009
CESAR1	0.45	coal (lignite)	15.2	5	6-8 ppm NO ₂ , 100-160 ppm NO _x	Niederaussem	Moser, 2022
CDRMax	0.15-0.2	CHP	3.7	14.9	11.3 NO _x	TCM, Norway	Hall, personal comm. , 2023
MEA	0.8-1.6	CHP (NGCC)	3.6-4	13-14	<5 ppmv NO _x	TCM	Morken, 2019
PZAS™	0.3/0.75	NGCC	4	12-14	<1 ppm	NCCC, Wilsonville, AL	Wu, 2021
PZAS™	0.6	synth NGCC	4	20	1 ppm	SRP, UT	Closmann, 2022
PZAS™	0.5	NGCC	4 (a)	8	0.5 ppm (b)	NCCC, Wilsonville, AL	UT, 2023

(a) Wet basis.

(b) Prescrubber reduced from 2.5 ppm to 0.5 ppm when online during campaign.



Solvent make-up rates

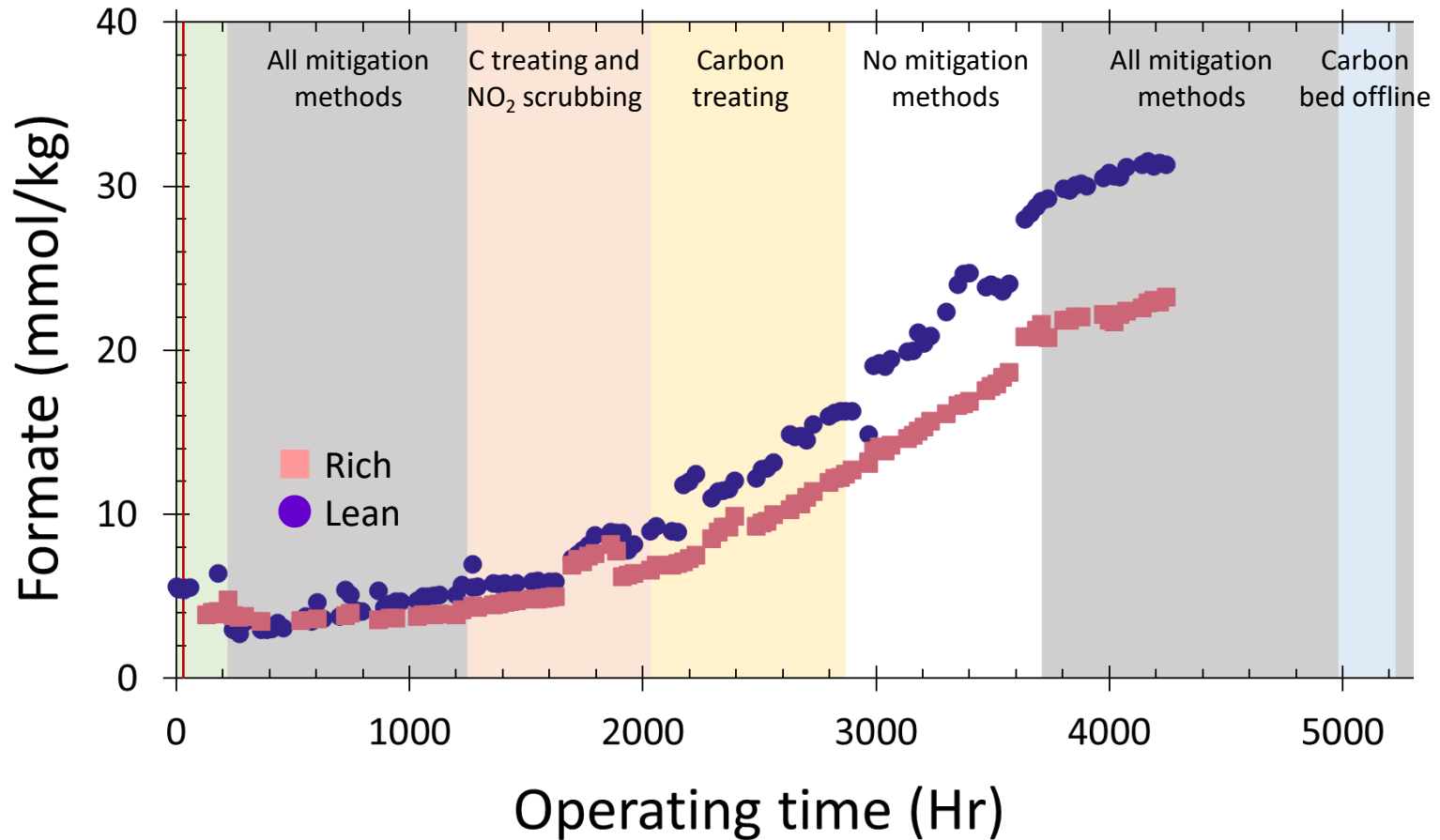
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PZAS™	0.6	synth NGCC	4	20	1 ppm	SRP, UT	Closmann, 2022
PZAS™	0.5	NGCC	4 (a)	8	0.5 ppm (b)	NCCC, Wilsonville, AL	UT, 2023

(a) Wet basis.

(b) Prescrubber reduced from 2.5 ppm to 0.5 ppm when online during campaign.



Degradation products by anion IC at NCCC (2023)



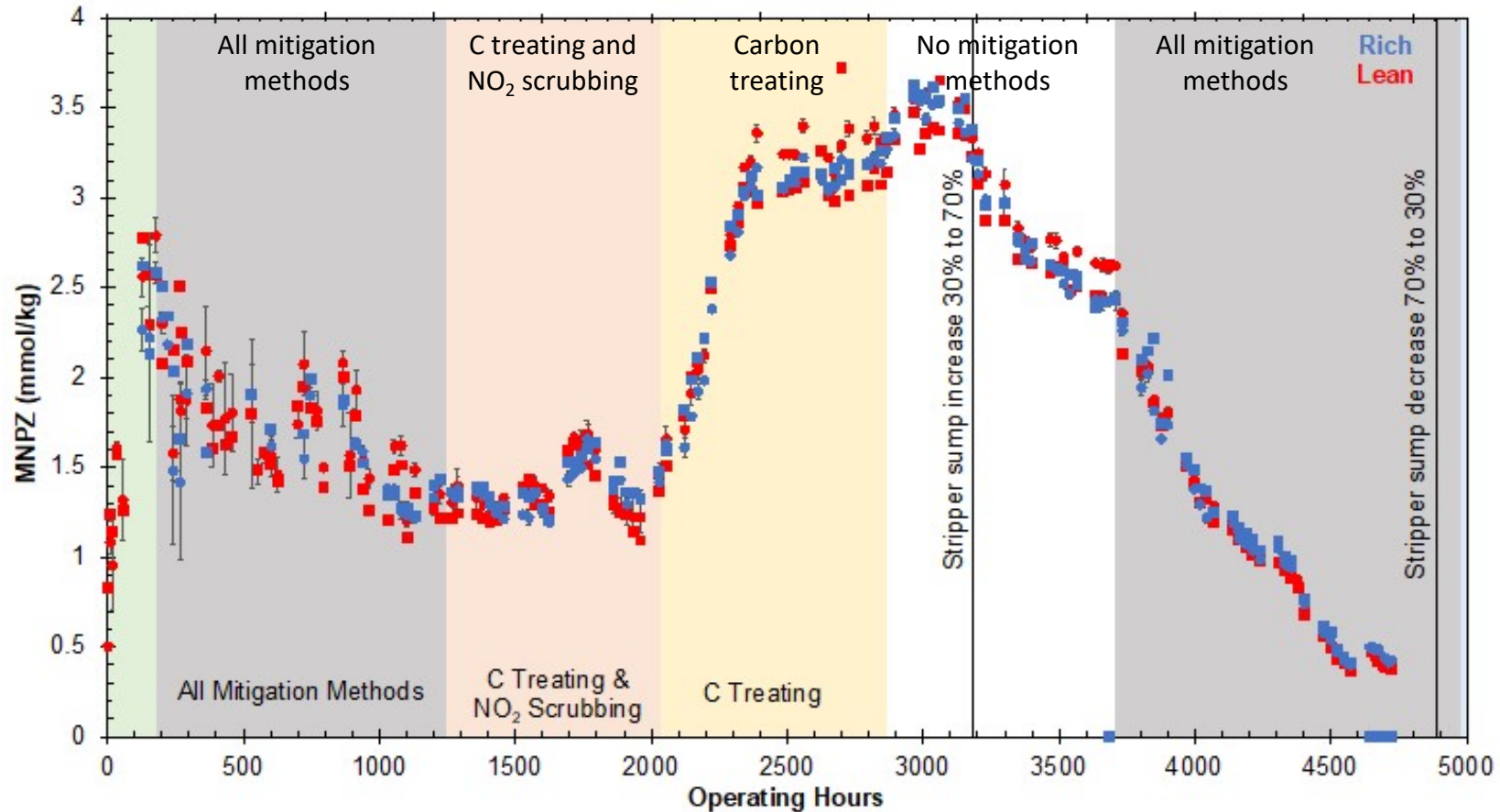


PTR-TOF-MS data – key takeaways

- FTIR measures NH_3 similar to TOF
- Other compounds (possibly PZ) interfere with FTIR's measurement of acetaldehyde
- Trickle bed performed nearly as well as other configurations for most compounds
- Acid wash reduced NH_3 95%; PZ reduced to below detection
- Introduced compounds (MeOH) easily detected

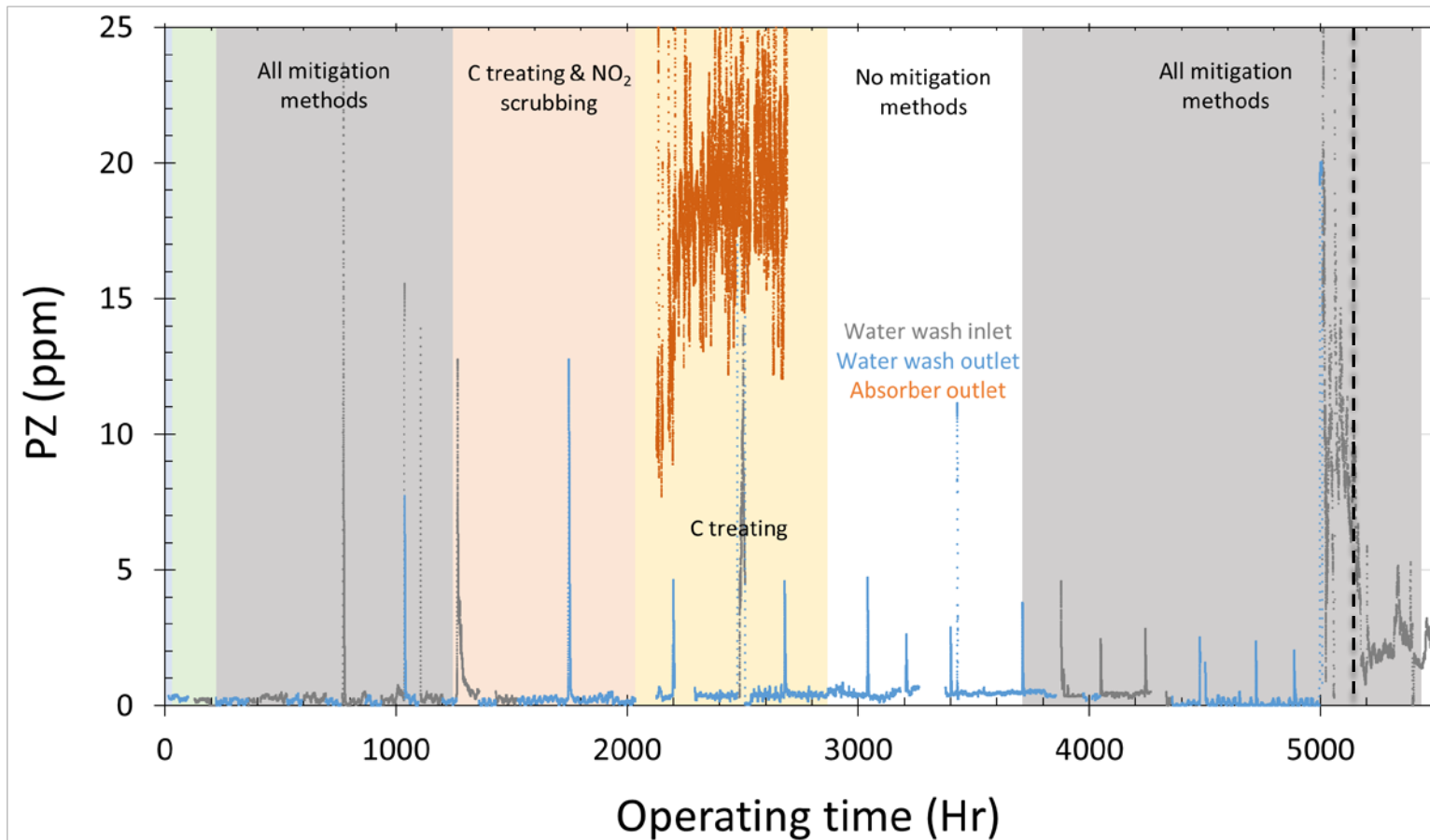


MNPZ by HPLC at NCCC (2023)



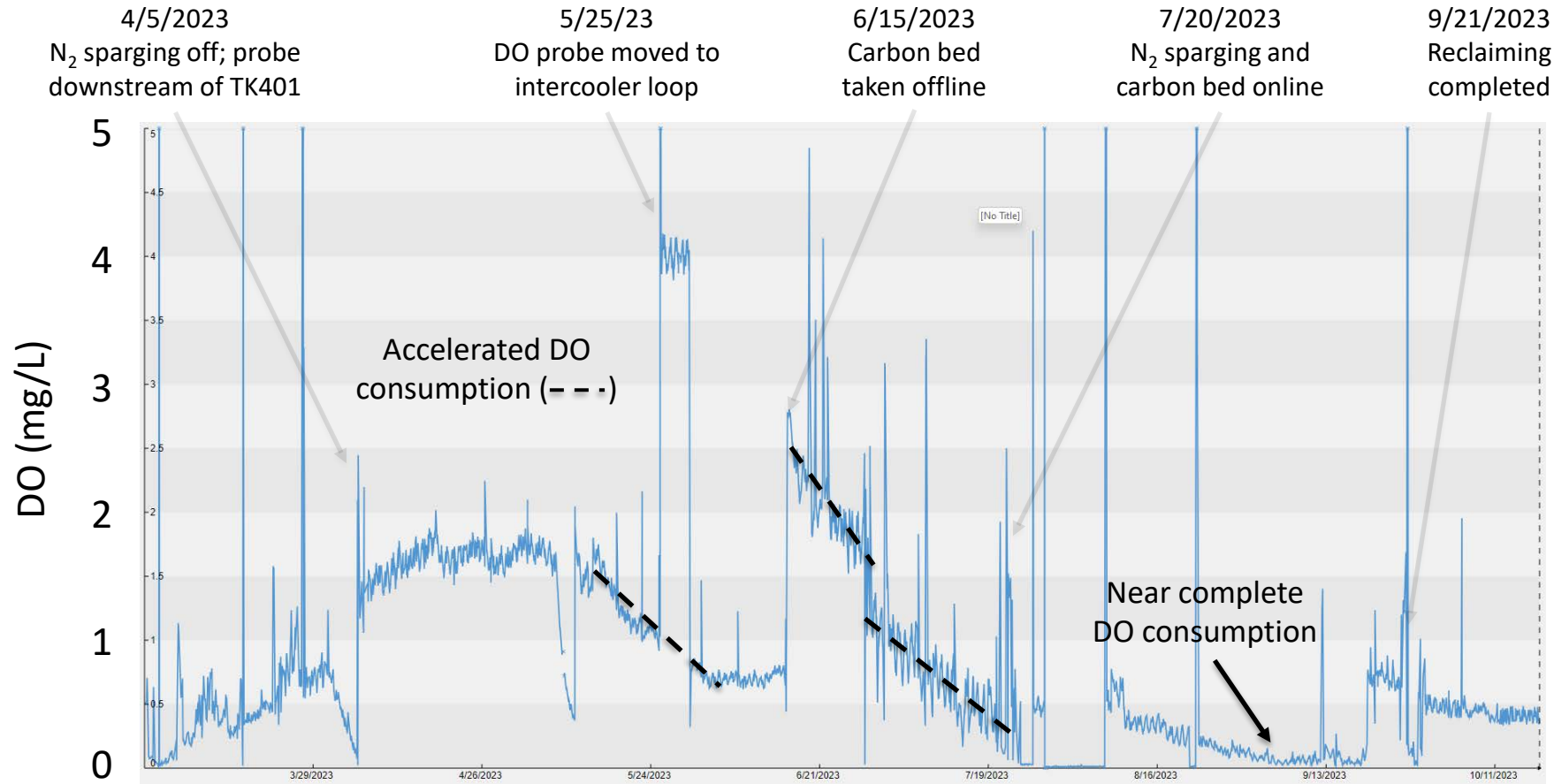


Flue gas monitoring data (FTIR)



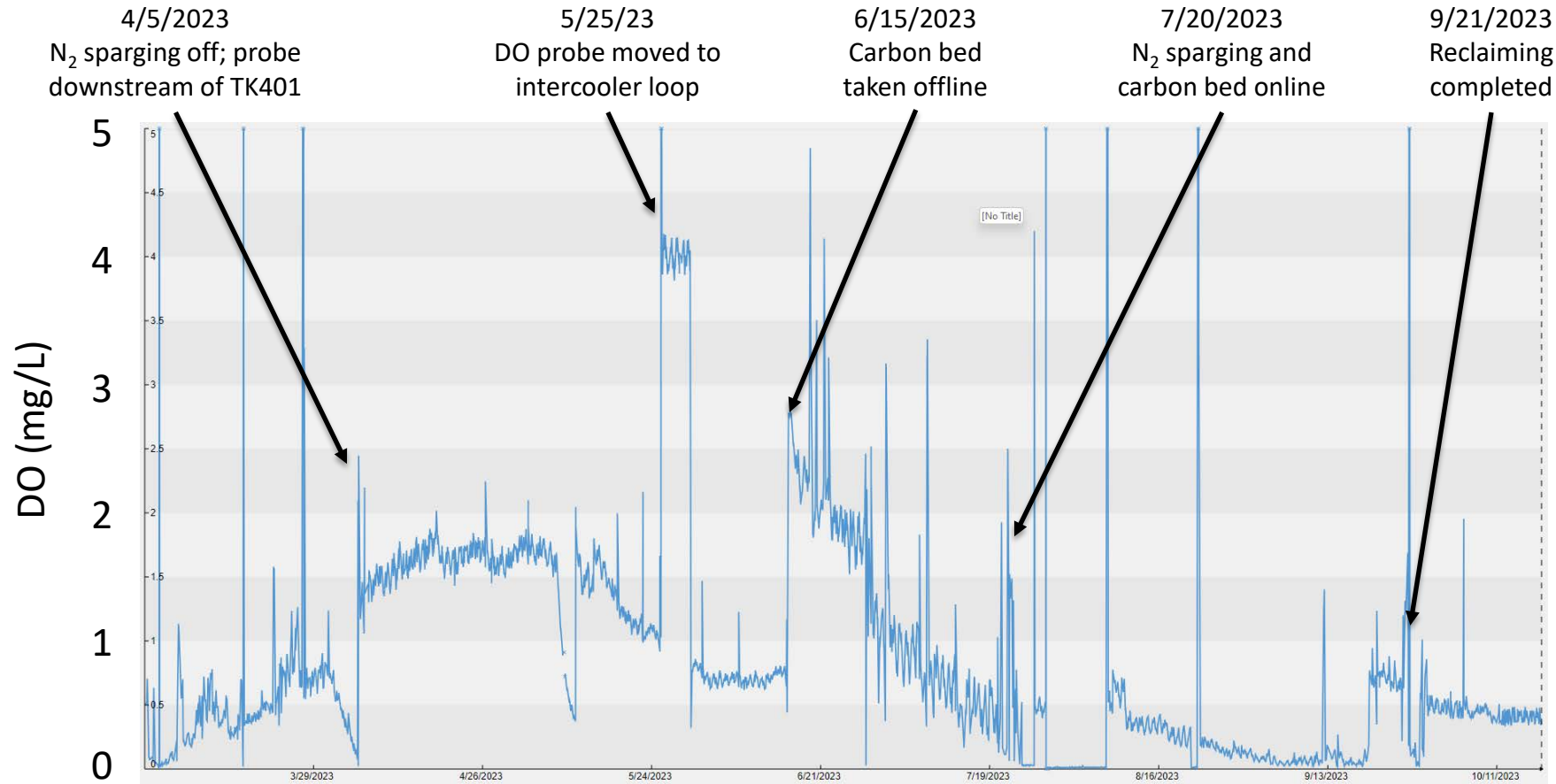


DO probe measurements



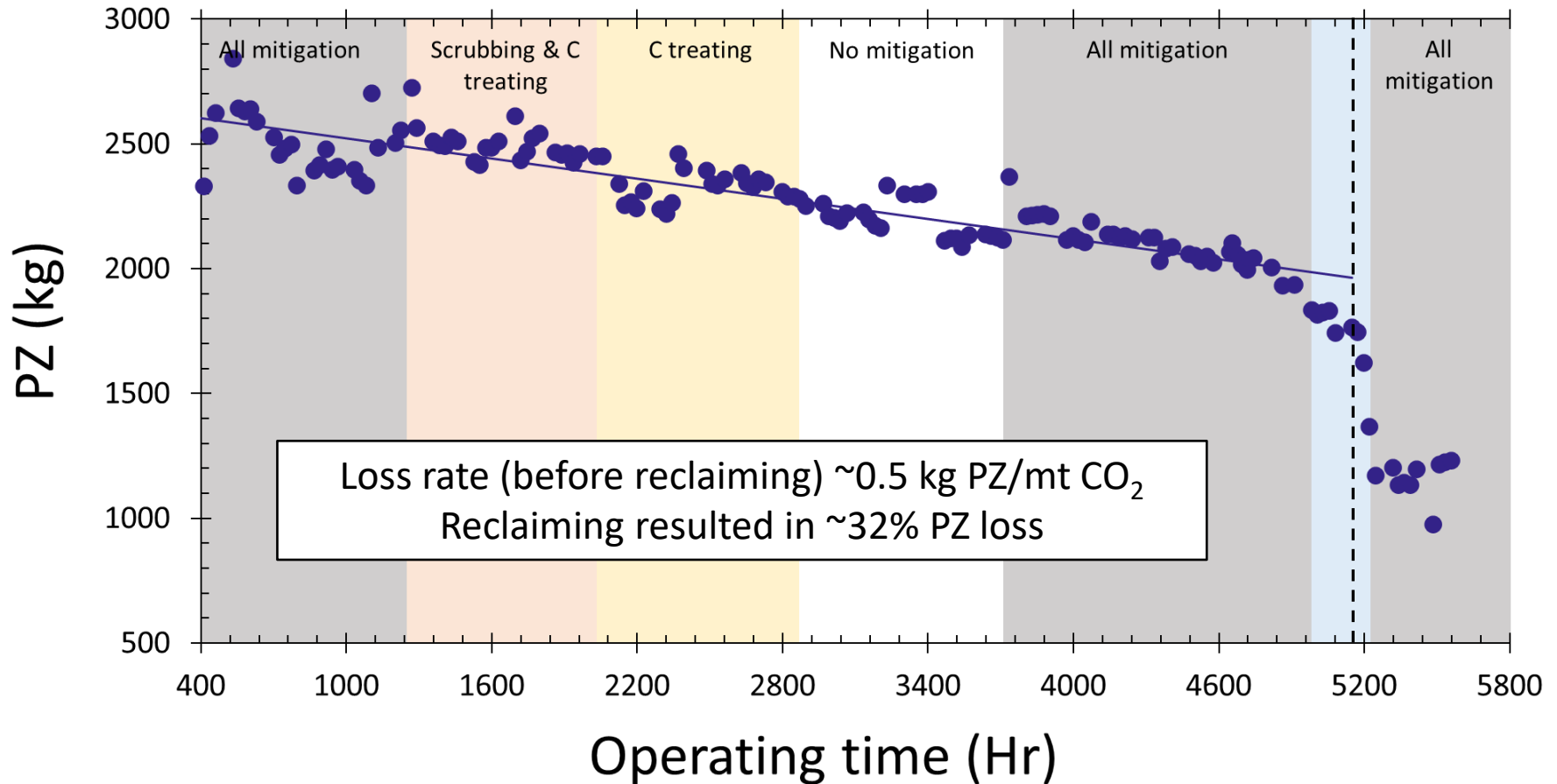


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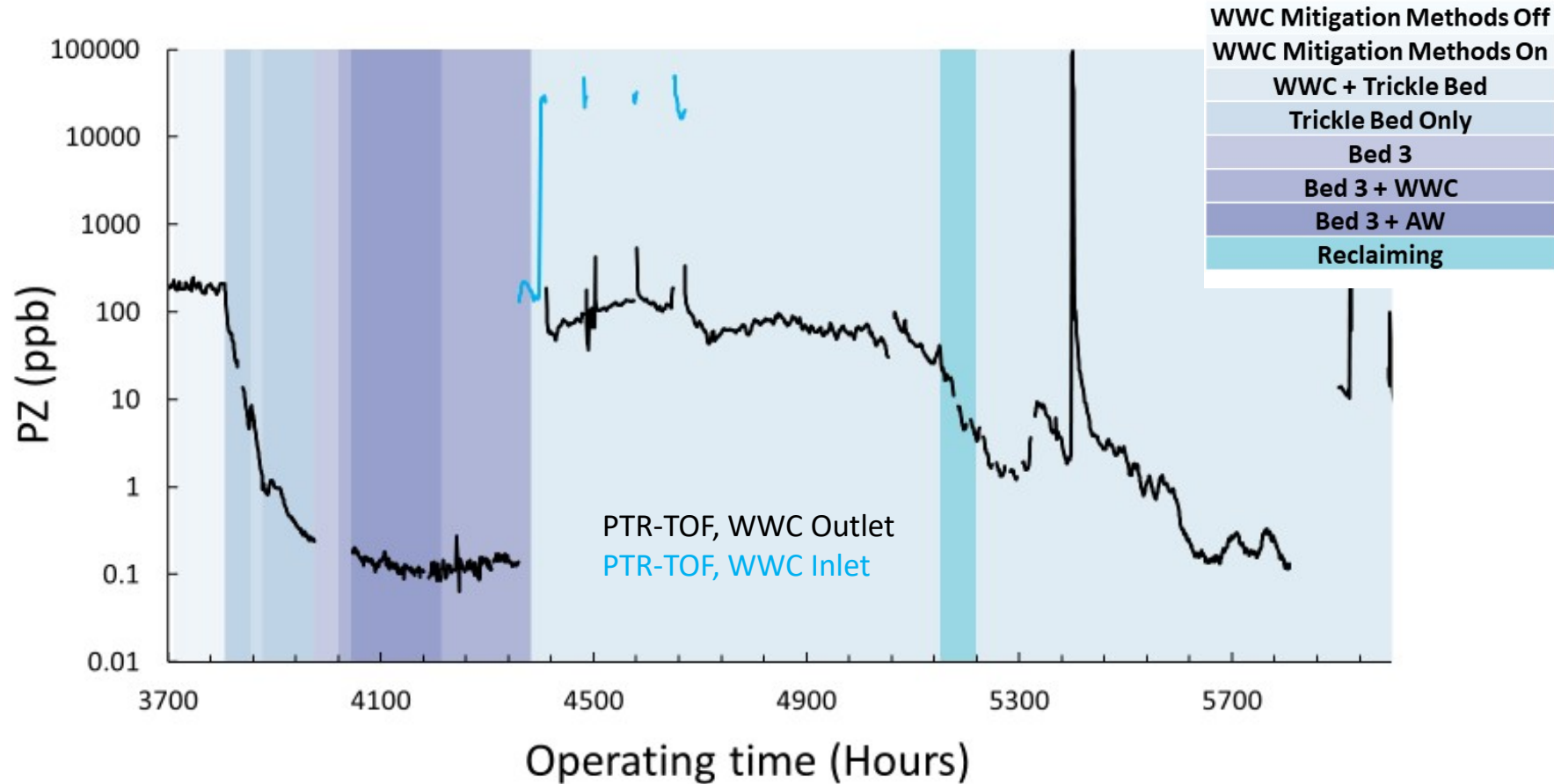


Solvent inventory



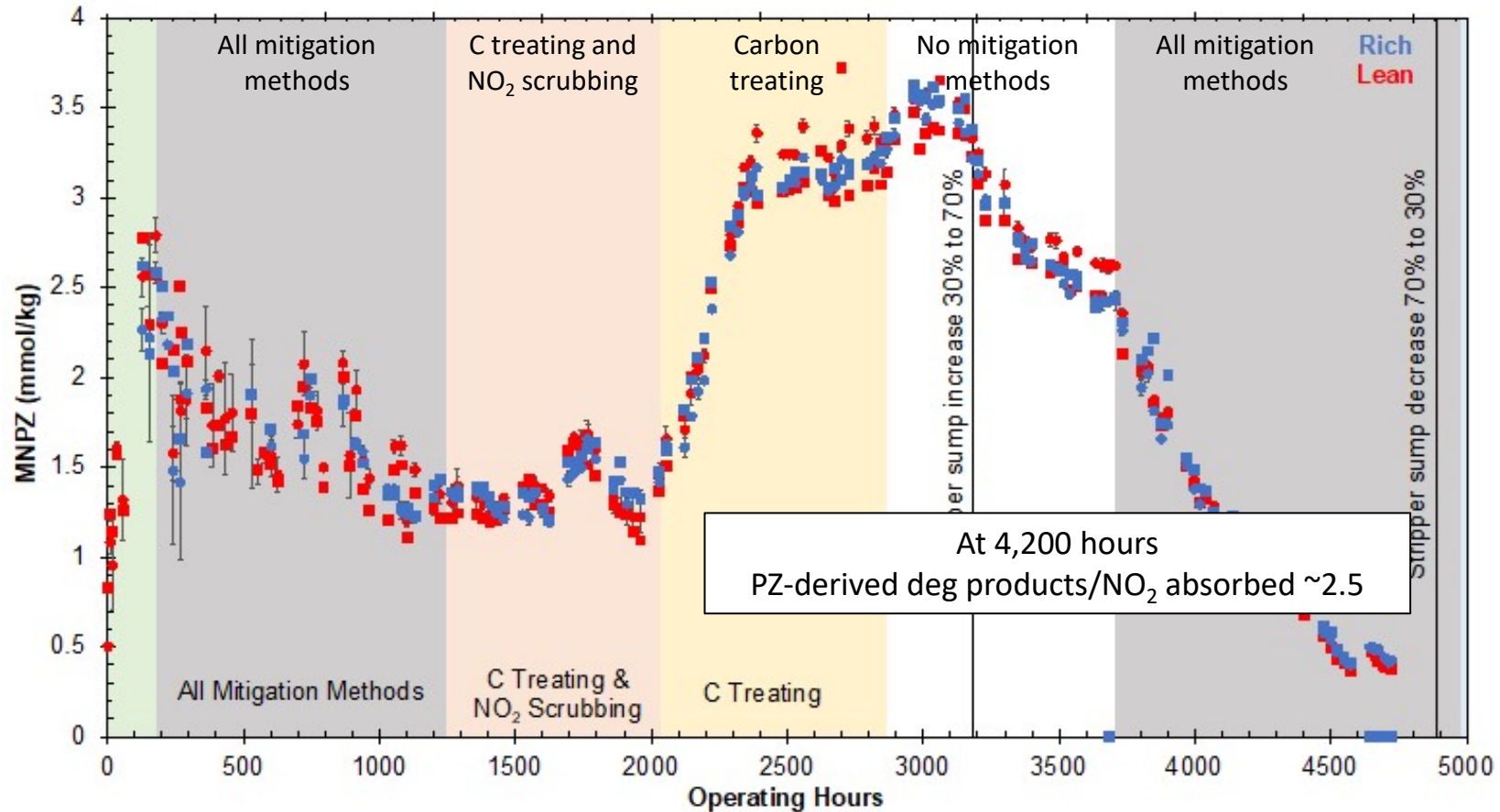


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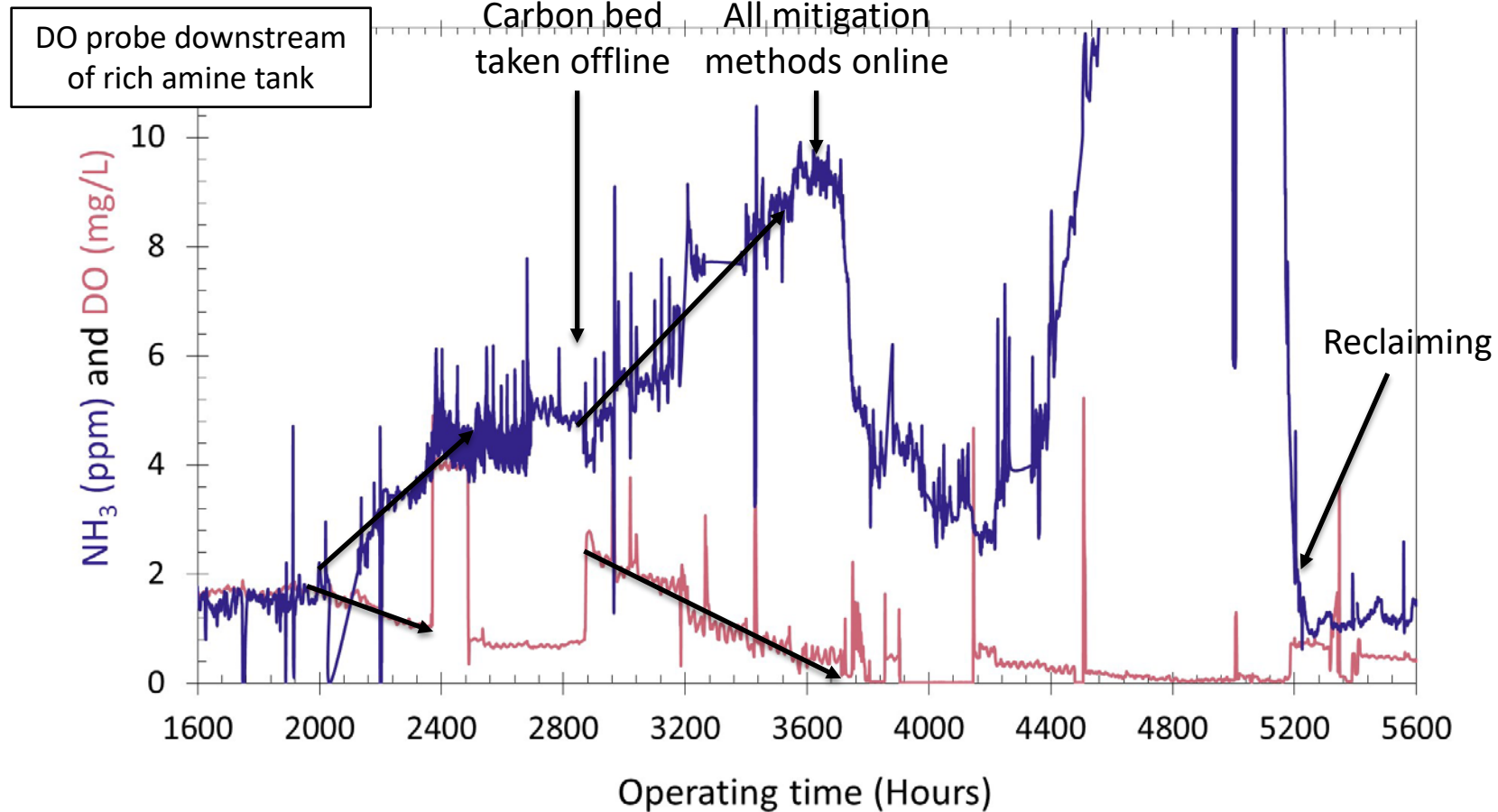


MNPZ by HPLC at NCCC (2023)





DO and NH_3 measurements





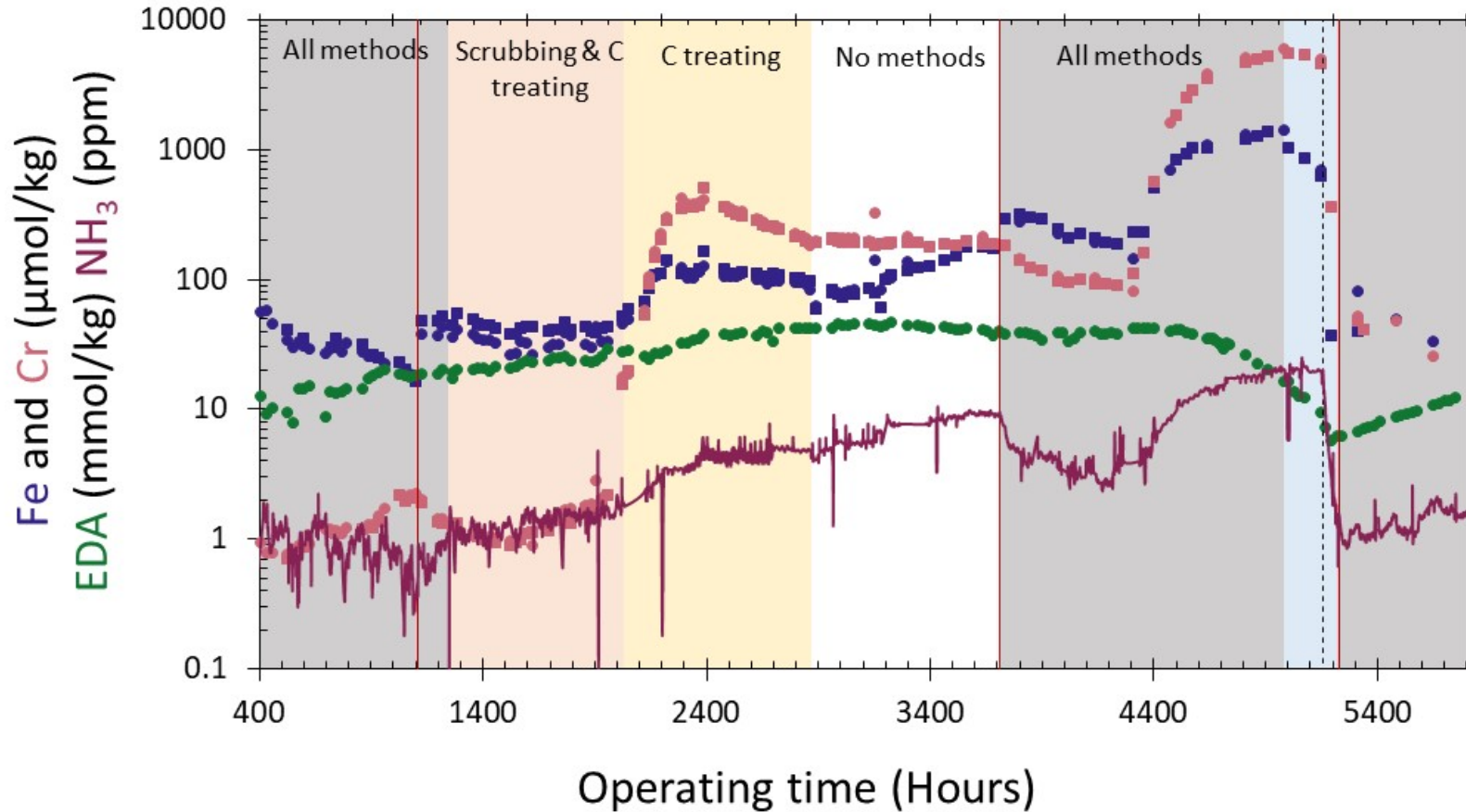
Solvent make-up rate

Methodology: Maintain PZ concentration at 30% (unloaded basis) and measure the loss of total solvent volume over the course of the campaign.

Loss rate before reclaiming was ~ 0.5 kg PZ/tonne CO₂.



Various species at NCCC (2023)





Carbon bed operations at NCCC (2023)



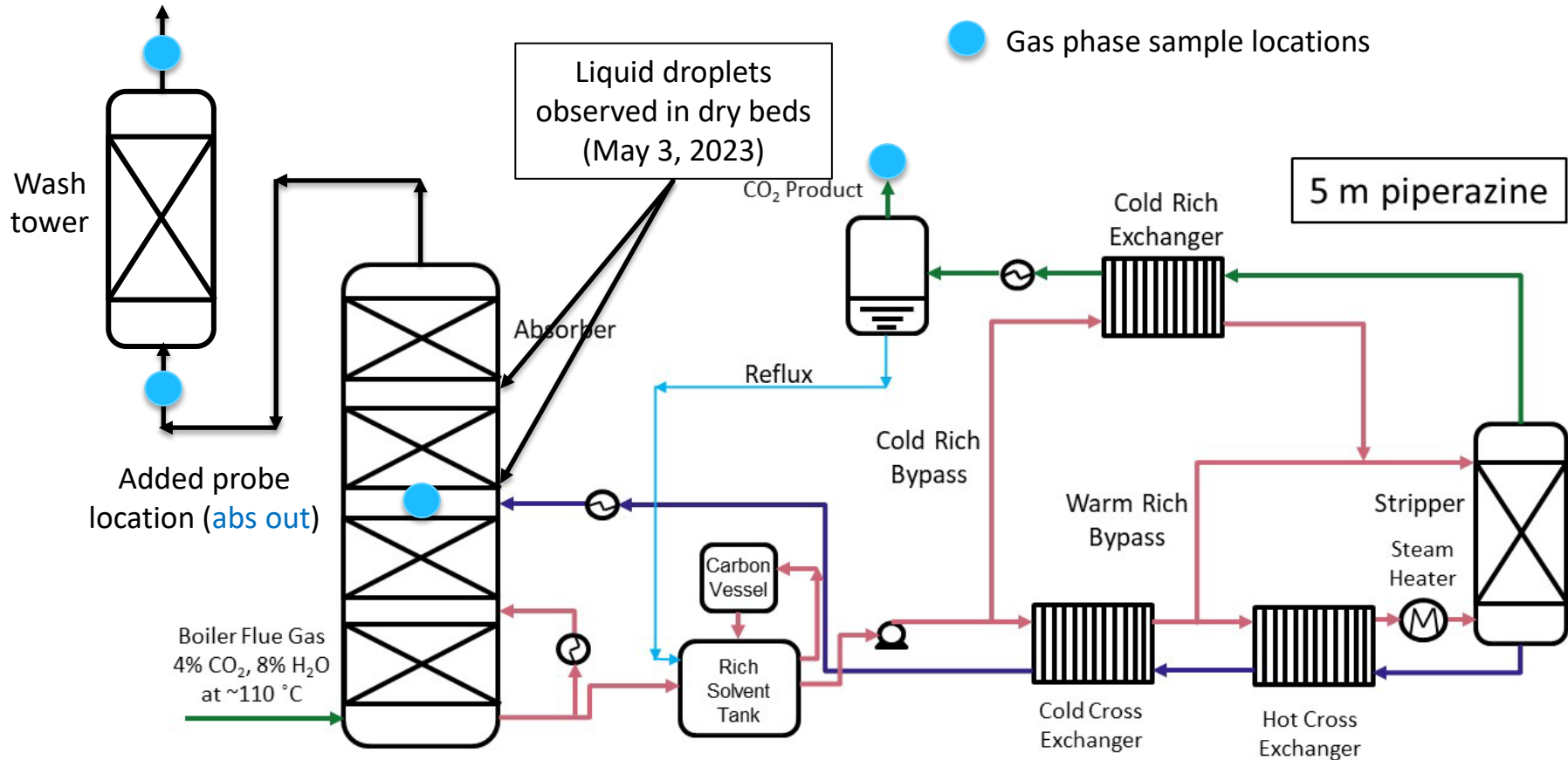
Carbon canisters removed/replaced after shutdown with $\sim 1,760$ hours in service.
(Second set)

Carbon canisters removed on 9/11/2023
after $\sim 1,290$ hours in service.
(Third set)



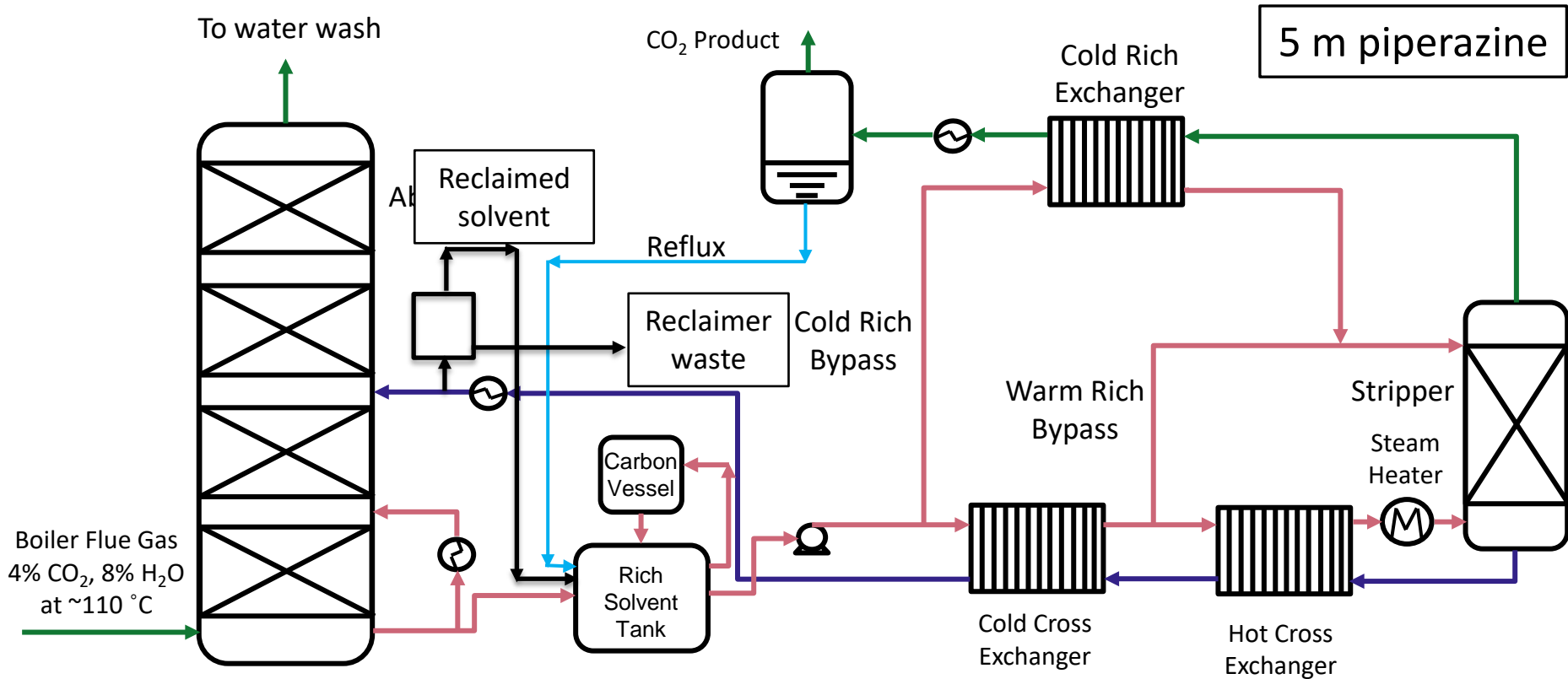


Gas phase monitoring locations (FTIR)





Reclaiming with PZAS™





UV-Vis absorbance at NCCC (2023)

