

CO₂ Capture by amine scrubbing

Yes! we are ready?

We have been ready since 2010!!

Will we make mistakes?

Fewer than in 2010!!

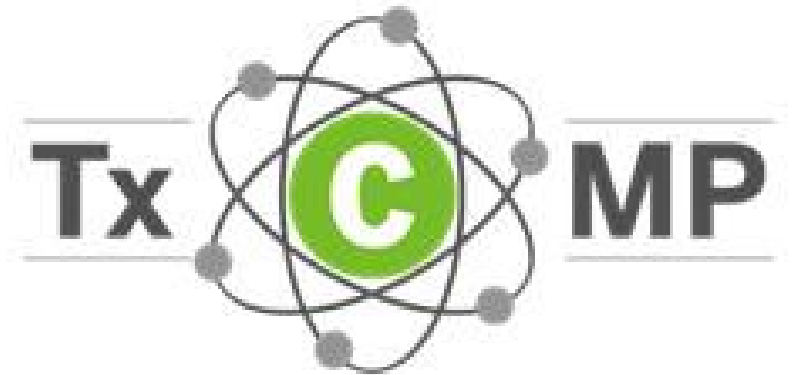
UTCCS-7, January 23, 2024

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Texas Carbon Management Program

Department of Chemical Engineering

The University of Texas at Austin



Research Needs for CO₂ Capture from Flue Gas by Aqueous Absorption/Stripping

Prepared for NETL/DOE

By Gary T. Rochelle et al., 2001

Recommendations for systematic research

- Explore MEA, Hindered Amines, promoted tertiary amines and K₂CO₃
- Measure
 - Thermodynamics, CO₂ solubility, Amine volatility
 - Kinetics of CO₂ absorption
 - Oxidative and Thermal Degradation
 - Reactions with NO_x, Nitrosamine
 - Catalysis by and reactions with Fe^{+2/+3}
 - Corrosion

Objectives of the TxCMP

- Train graduate and undergraduate students
- Create understanding, data, and methods to facilitate deployment of CO₂ capture
- Create innovations to enhance performance and reduce cost of CO₂ capture

Strategy

- Apply ChE science to understand and quantify the performance of MEA & PZ absorption/stripping.
- Develop innovative, evolutionary improvements.

82 TxCMP Students on amine scrubbing 2000-2025

- **18 - Thermodynamics & rates** – Dang, Cullinane, Hilliard, Nguyen, QXu, XChen, LLi, Bishnoi, Culinane, McLees, Dugas, Rafique, Zhou, HLi, Du, Yuan, Fliu, Wanderley
- **16 - Modeling** - Freguia, Oyenekan, Cohen, Plaza, Frailie, Sachde, Walters, Madan, YJLin, VanWagener, Ding, Rezazadeh, Gao, Abreu, Martinell, Suresh Babu,
- **13 - Oxidation** - Chi, Jones, Goff, Alawode, Sexton, Freeman, Voice, Vevelstad, Nielsen, Liu, Wu, Plantz, Obute
- **8 - Emissions** – Fulk, Beaudry, Liu, Kang, KLi, Zhang, Akinpelumi, Drewry
- **5 - NO₂/Nitrosamine** – Ashouripashaki , Fine, Goldman, Selinger, ClChen
- **5 - Thermal Degradation** – Davis, Freeman, Closmann, Namjoshi, Hatchell
- **4 - Contactor Characterization** – Wilson, Tsai, Wang, Song
- **3 - Pilot plant and corrosion** - ECHen Fischer, CTLiu

“A Perspective on Amine Scrubbing for CO₂ Capture” Gary T. Rochelle, Science 2009

Amine scrubbing ...used to separate ...CO₂ from [CH₄ and H₂] since 1930.

Fluor used MEA on gas boilers, fired heaters. & gas turbines.

Lummus used MEA on coal.

MHI used KS-1 on fired heaters.

[Amine Scrubbing] is...robust and ready to be...to be used for CO₂ capture from coal ...power plants.

Process & solvent improvements should reduce the energy consumption to 0.2 MWh/t CO₂.

..will be applied first on large coal-fired boilers with 12% CO₂.

.....useful with biomass boilers at 14% CO₂, cement plants at 25% CO₂, and steel at 25% CO₂.

.....less useful on NGCC at 4% CO₂ or gas- or oil-fired boilers/heaters at 7% CO₂.

From **Lubbock, TX** to **Thompsons, TX**



Gary T. Rochelle , TxCMP

GHGT-12, 2014

2G amine scrubbing on coal will be realized at Thompsons &
Boundary Dam

2G systems will use less energy than Lubbock

50% less reboiler duty, 30% less W_{eq}

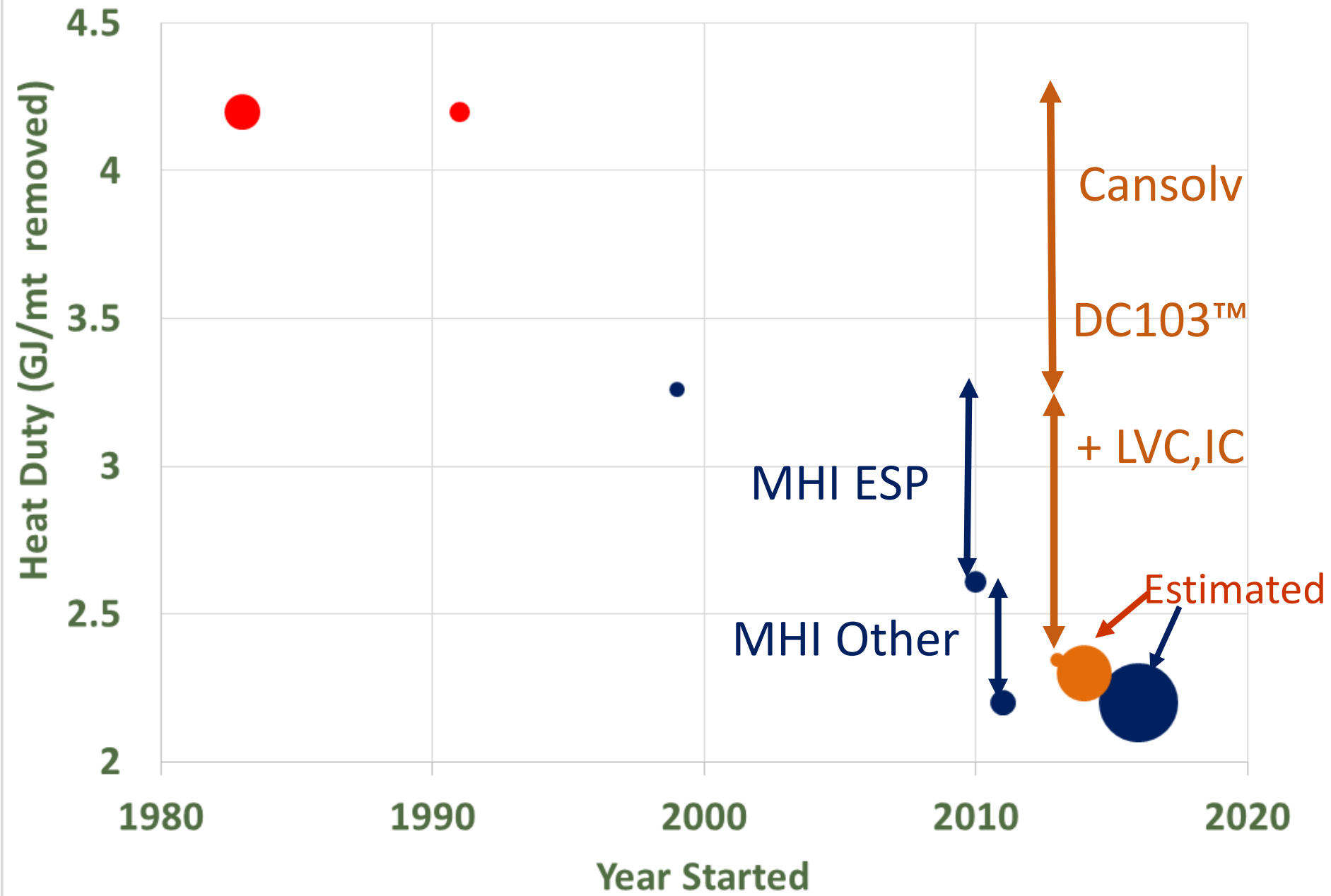
Better solvent

Better flowsheet

3G systems will not be much better

2G systems will manage solvent oxidation and aerosol emissions

Effect of flowsheet enhancements



In 2024, We have....

- Fluor et al. experience with MEA
- 2 large scale coal-fired systems
 - 110 MW Boundary Dam - Cansolv (Shell)
 - 250 MW Petra Nova – KS-1 (MHI)
- Many developers and more 2G solvents
 - KS-21 (MHI)
 - Aker Clean Carbon
 - Carbon Clean Solutions
 - BASF
 - Ion Engineering
 - Honeywell UOP
 - Toshiba/Lummus
 - SLB/RTI
 - Et cetera

Annual TxCMP Funding

- **\$850k Texas Carbon Management Program**
- **\$100k CCSI² (DOE)**
- **\$150k Amine Oxidation (DOE)**
- **\$600k State of Texas – Ovhd & faculty salary**

- **\$1700k – Total Annual Program Funding**





TxCMP

17 Industrial Sponsors

Oil

Aramco
BHP
Chevron
Exxon
Total
INPEX

Suppliers

Shell/Cansolv
MHI
Honeywell UOP
SLB/RTI
Carbon Clean
Solutions
Axens

Utilities

EPRI
Calpine
SK
Drax

Government

DOE/NETL
LEIDOS/CCSI²

6 PHD students working on amine scrubbing

2017	2018	2019	2020	2021	2022	2023	2024	2025	
		Suresh - Stripper Modeling							
		Abreu - Absorber Modeling							
		Drewry - Water Wash Model							
				Martorell - Optimization					
Wu - oxidation									
Liu - Corrosion									
			Plantz - oxidation by Fe^{+3}						
			Chen - Oxidation by NO_2						
			Obute - Oxidation by dissolved O_2						

TxCMP Available Resources for Solvent Characterization

- Fred Closmann – Research supervisor
 - 2007-11 UT PhD, 2011, Oxid. & thermal degradation of MDEA/PZ
 - 2011-19 Phillips solvent development, FCC
 - 2020 - UT PZ pilot plant operations, analysis, & reporting
 - 2020 - UT Analytical supervisor
- Bench-scale solvent characterization with 23 yrs experience
 - Oxidative Degradation
 - Thermal Degradation
 - Amine volatility and CO₂ solubility at absorber conditions
 - Wetted Wall column rate and solubility measurements

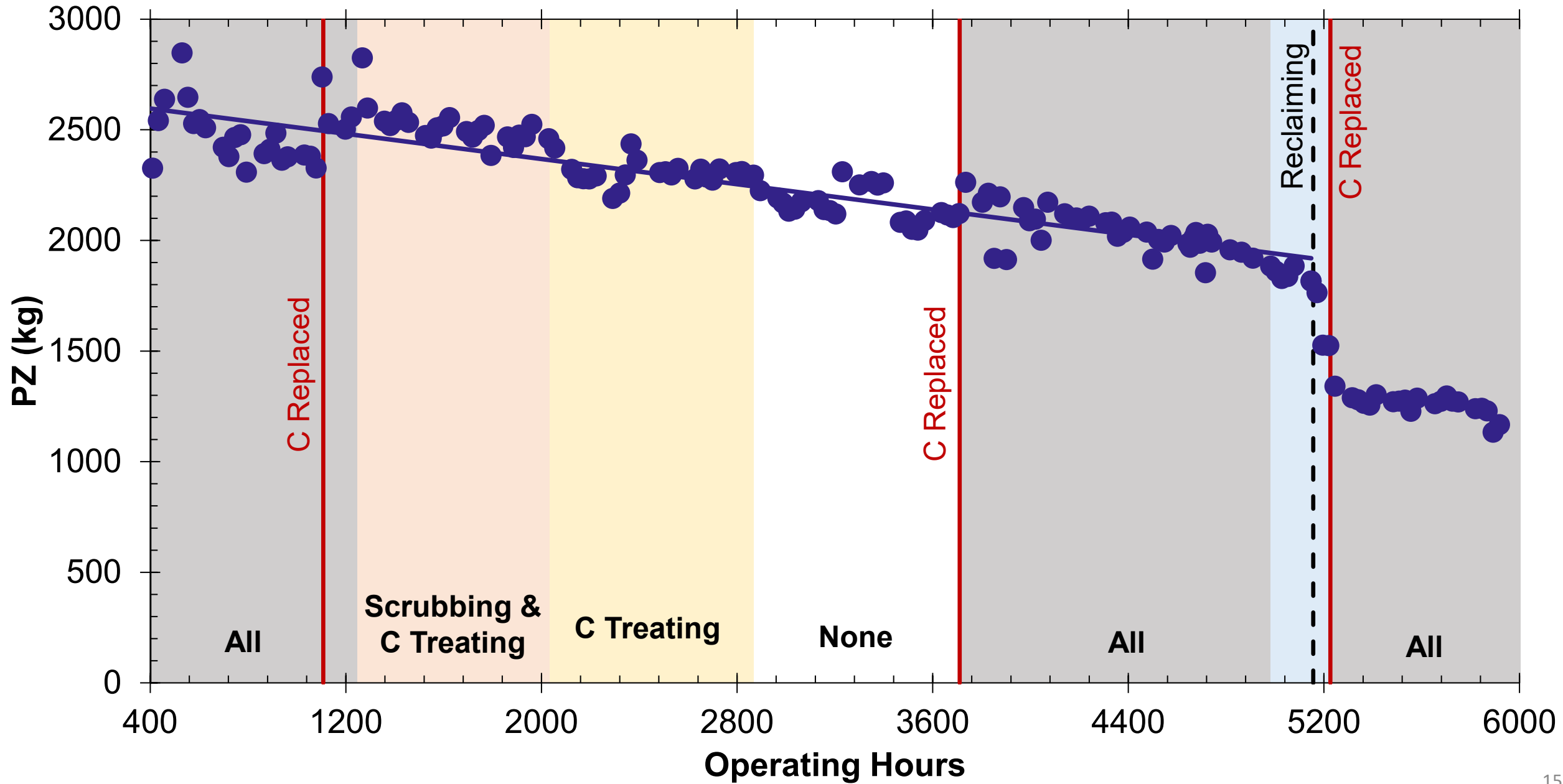
Pilot Test of PZAS at NCCC: Targeting oxidation (12/22-10/23)

180 h	1067 h	786 h	835 h	841 h	1272 h	173 h	67 h	698 h
	Carbon Treating			No Mitigation				
	NO ₂ Scrubbing							
N ₂ Sparging								
							Reclaiming	

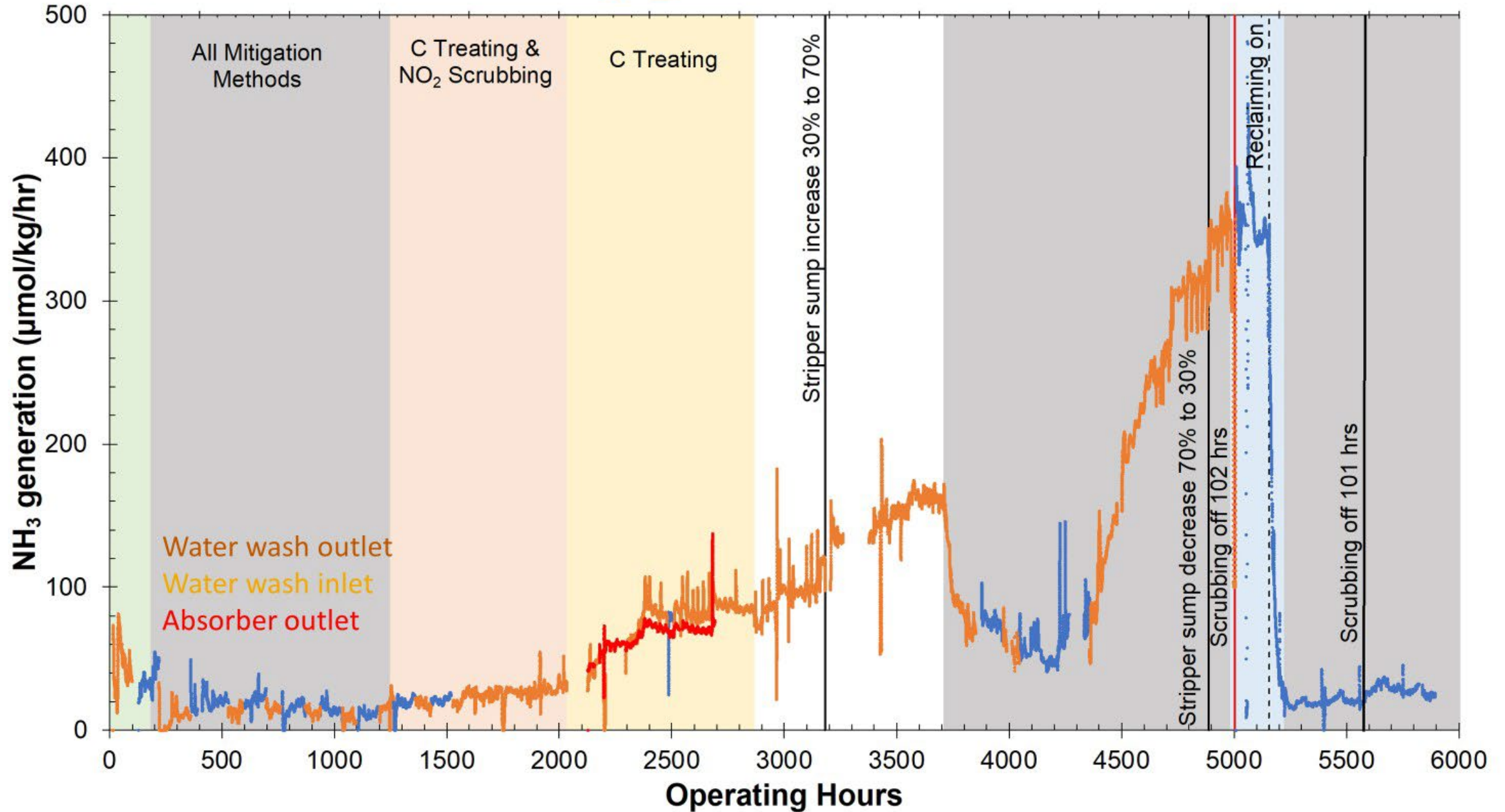
TxCMP Results: PZAS testing at NCCC

- **Wisthaler, T 2:14; Misztal, T 2:45**
 - Emissions include unexpected possibly problematic components, usually at low levels.
- **Closmann, T 3:30, W 11:38**
 - Overall Summary
 - Uncontrolled oxidation occurs with accumulated products.
 - Nitrogen sparging reduces oxidation early in campaign.
- **Carter, W 10:30**
 - Aminoacids are significant class of degradation products.
- **Chen W 1:30**
 - 2.5 ppm NO₂ results in significant oxidation.
 - NO₂ can be managed by sulfite scrubbing.
- **Plantz, W 1:50**
 - Carbon treating suppresses oxidation.
 - 2 corrosion events associated with increasing oxidation.
 - Reclaiming is effective at restoring solvent & suppressing oxidation.
- **Drewry, W, 4:30**
 - Water wash & acid wash effectively manage emissions.

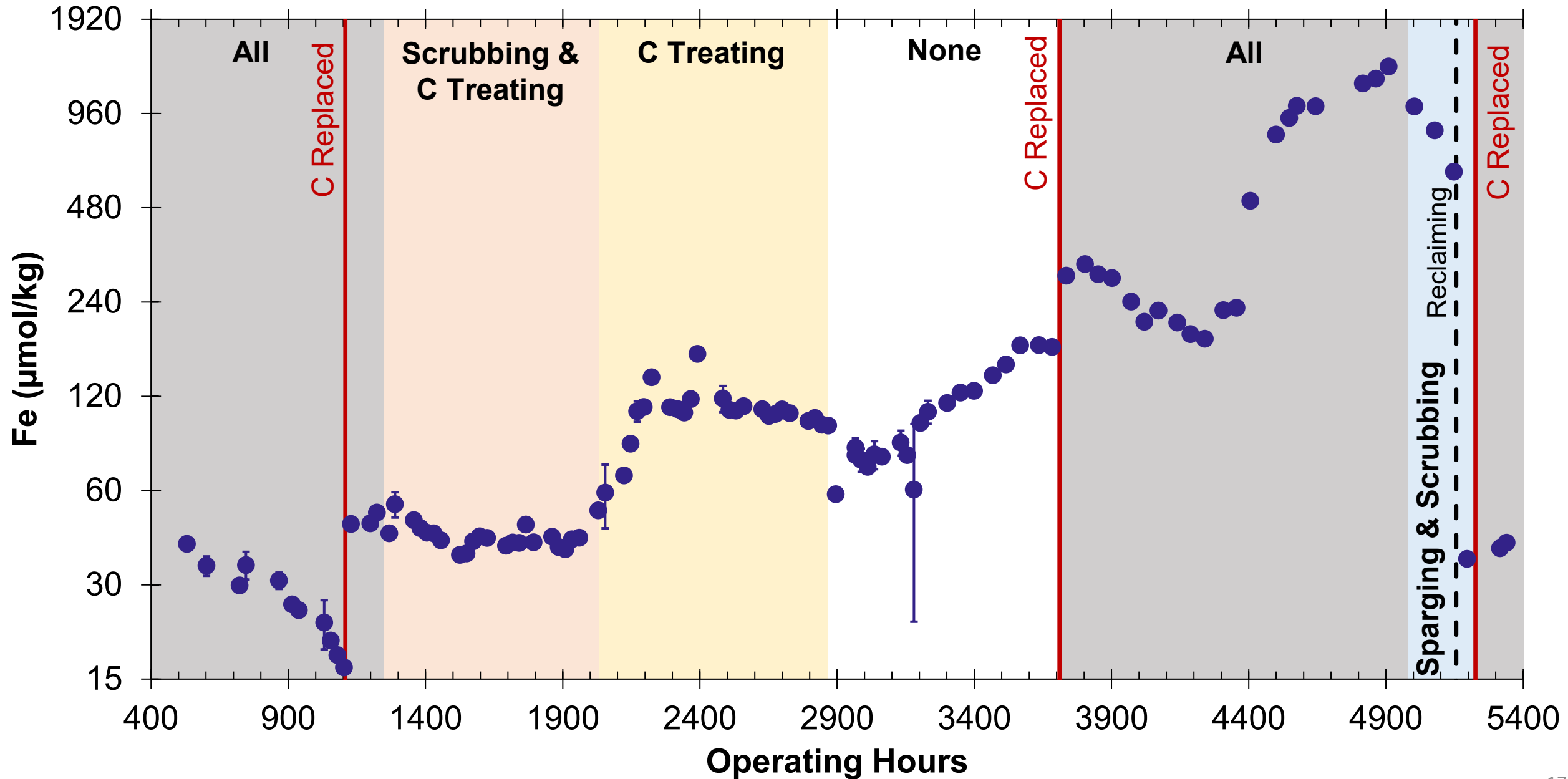
PZ Inventory



NH₃ generation



Carbon Treating and Reclaiming Decreases Fe Solubility



- **Bench-Scale Results**

- Chen W 9:14 – Screening of amines for oxidation w & w/o NO₂
- Obute W 10:50 - Measuring oxidation as oxygen consumption

- **Process Modeling to Guide the Future**

- Abreu Th 9:14 – Crossflow contacting to reduce absorber height
- Martinell Th 10:30 – Equation-based modeling to Optimize design

19 Additional Presentations from UT & International Collaborators

- UT – Waxman, Mizstal, Baldea, Brennecke, Freeman, Mullins
- University of Oslo - 1
- NTNU – 2
- RWE – 1
- TNO – 1
- Tsinghua University -1
- Nagoya University – 2
- Politecnico di Milano -1
- National Tsing Hua – 1
- Univ of Kentucky – 2
- Aramco – 1
- EPRI-1
- PNNL – 1
- NETL - 2

Future meetings on amine scrubbing

June 5, 2023 – TxCMP sponsors review, Austin

August, 2023 – DOE Contractors review, Pittsburg

October 20-24, 2024 – GHGT-17 - Calgary

Oct. 25 – TxCMP/NTNU/KY/etc. collaboration

Highly Recommended

TxCMP submitted 11 abstracts

Continuing Achievements of the TxCMP

- Training graduate and undergraduate students
- Creating understanding, data, and methods to facilitate deployment of CO₂ capture
 - Especially amine oxidation and air emissions
- Creating innovations to enhance performance and reduce cost of CO₂ capture

Pilot Plant and Lab Tours

- At 4:45 or 5:10 , find Maeve in the Commons
- For later tours find sign at reception
- Hard hats and safety glasses provided
- Closed toes shoes & long pants required