

# 5 m PiperaZine with the Advanced Stripper (PZAS™) at the NCCC pilot plant

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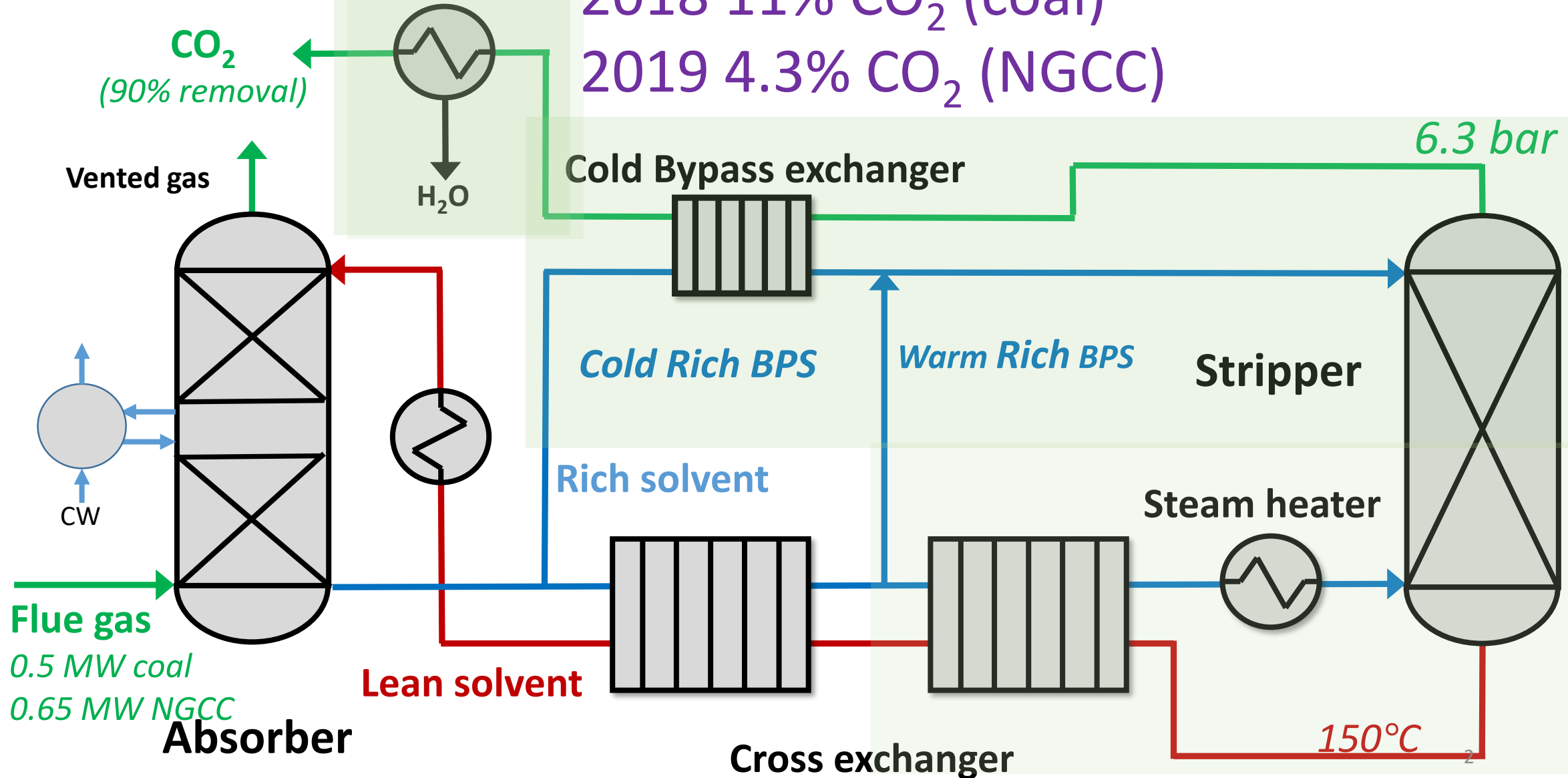
DOE funded coal testing by AECOM, Trimeric, & UT

CCP4 funded NGCC testing by UT

# PZAS<sup>tm</sup> at NCCC: New Equipment 2018

2018 11% CO<sub>2</sub> (coal)

2019 4.3% CO<sub>2</sub> (NGCC)



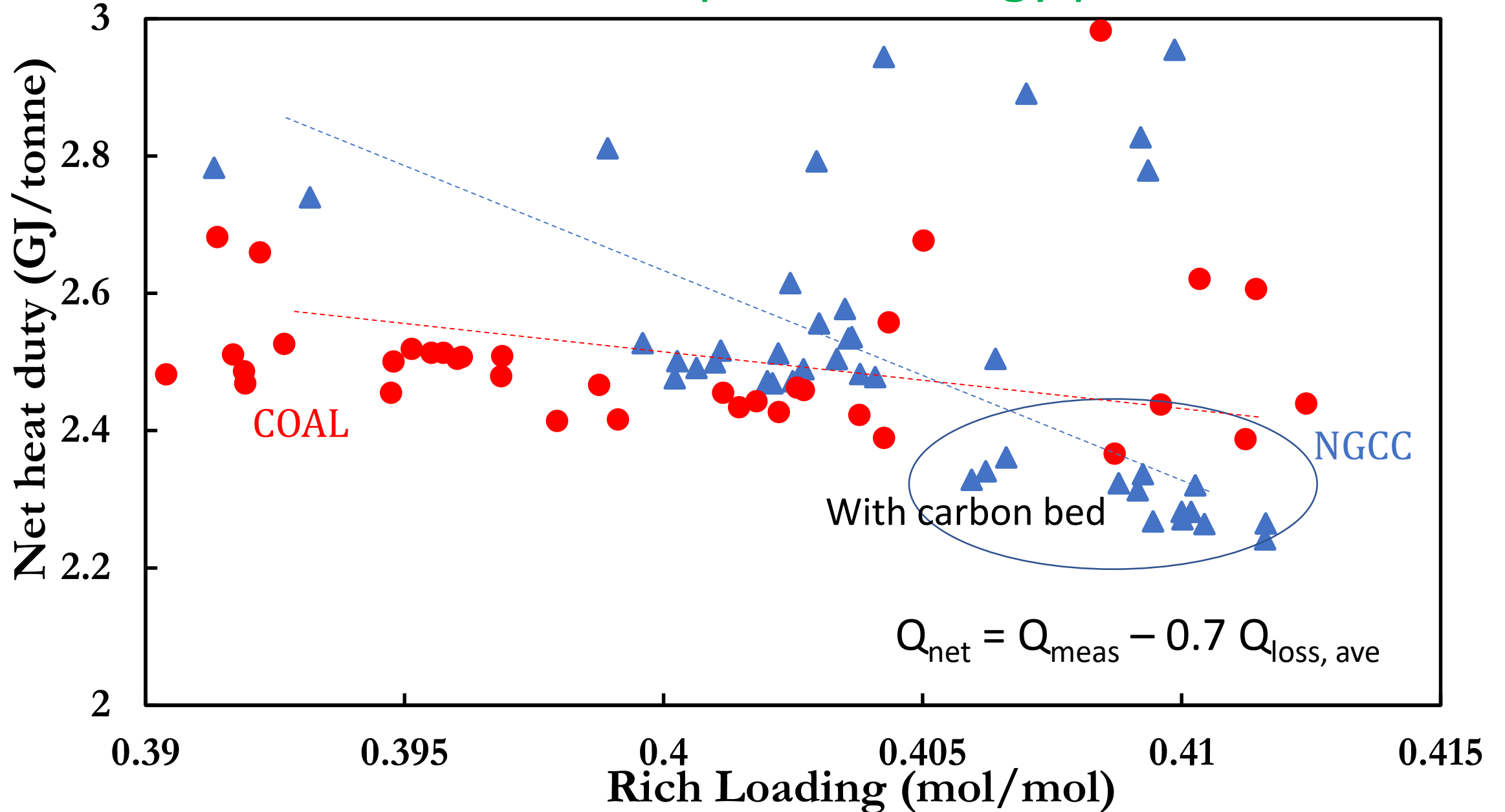
## Previous PZAS R&D prepared well for pilot testing

- (2000-20) Research by 43 graduate students
  - Fundamental basis & models of performance
    - Measurement of thermo, rates, packing performance
    - Rigorous, validated AspenPlus
  - Bench-scale work on oxidation, corrosion, amine aerosol
- (2010-09) Pilot with 17-in absorber, 4-20% CO<sub>2</sub> in air, 2000 hrs

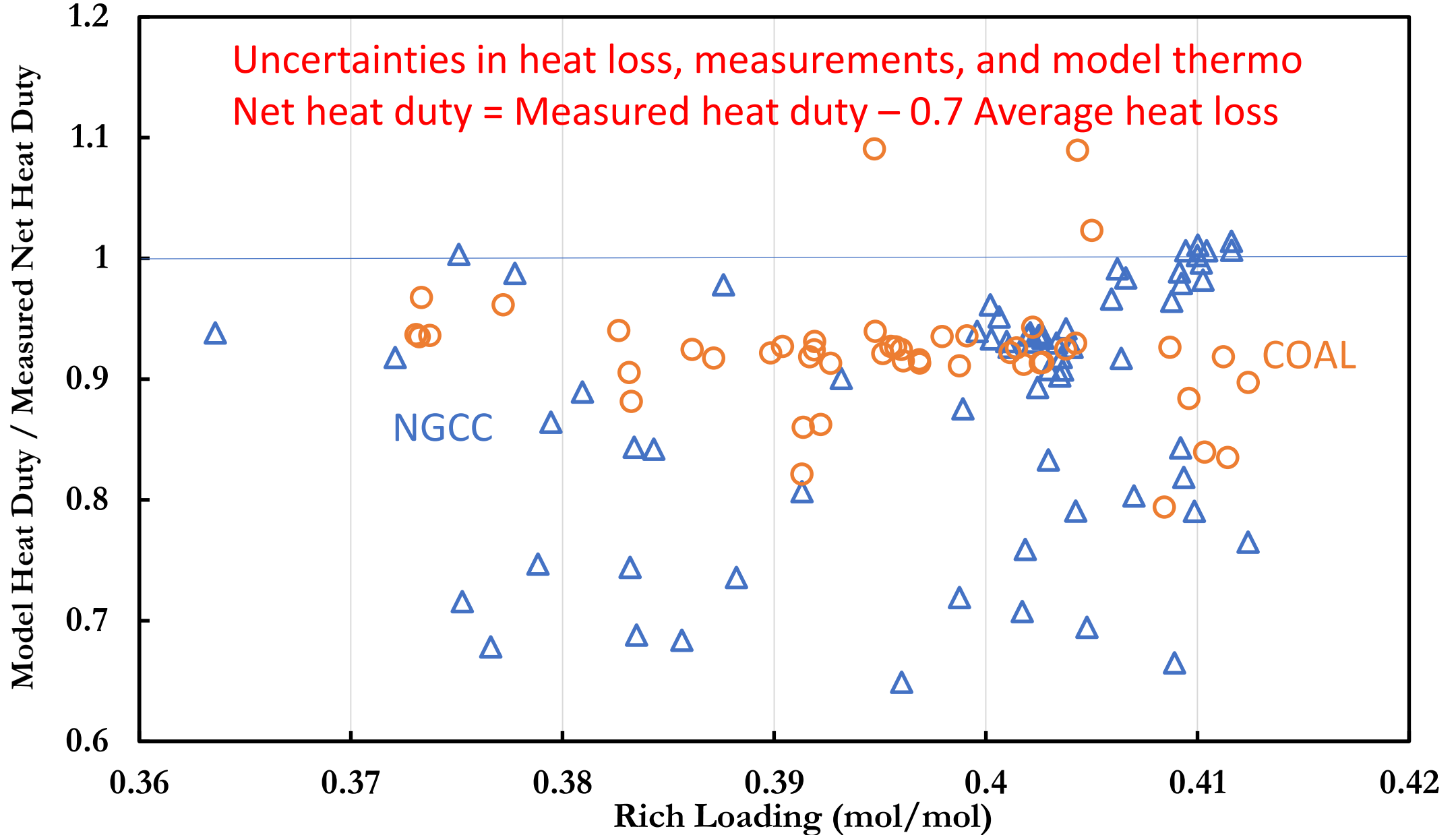
# [PZAS™] : 2 campaigns at NCCC

	Coal (2018)	NGCC (2019)
Flue gas	11% CO <sub>2</sub>	4% CO <sub>2</sub>
Reliable design and operation -- no precipitation		
Opt Q <sub>stm</sub> (GJ/t) at 150°C, 6-7 bar	2.0-2.1	2.0-2.2
CO <sub>2</sub> removal (%) w 40 ft packing	90-98	80-96
Low Oxidation (kg PZ/t CO <sub>2</sub> )	0.1	0.3
Low PZ emissions (ppm)	0.5-5	0.5 – 2
Corrosion acceptable with CS and 304 SS		

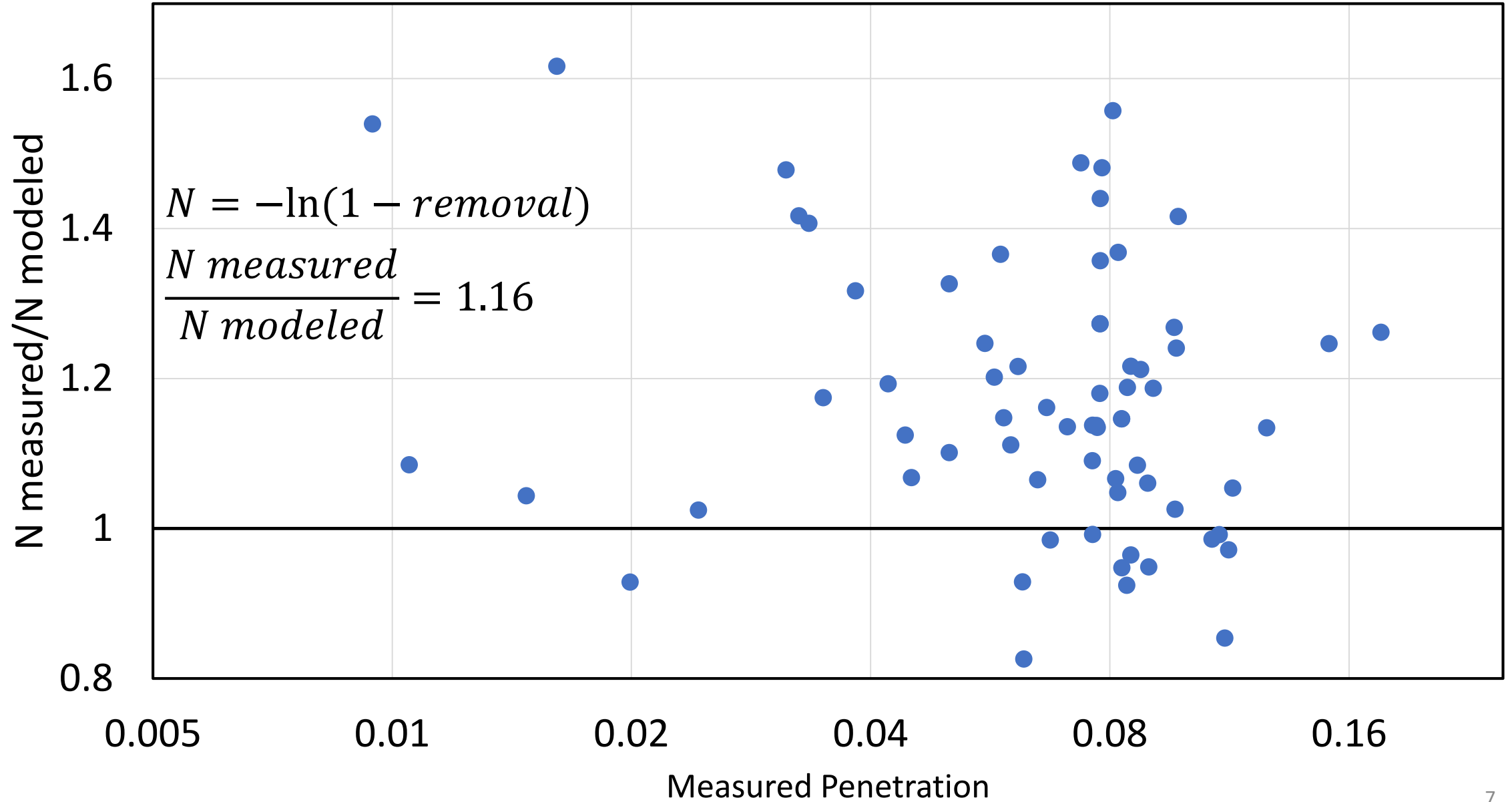
# Pilot demonstrated expected energy performance



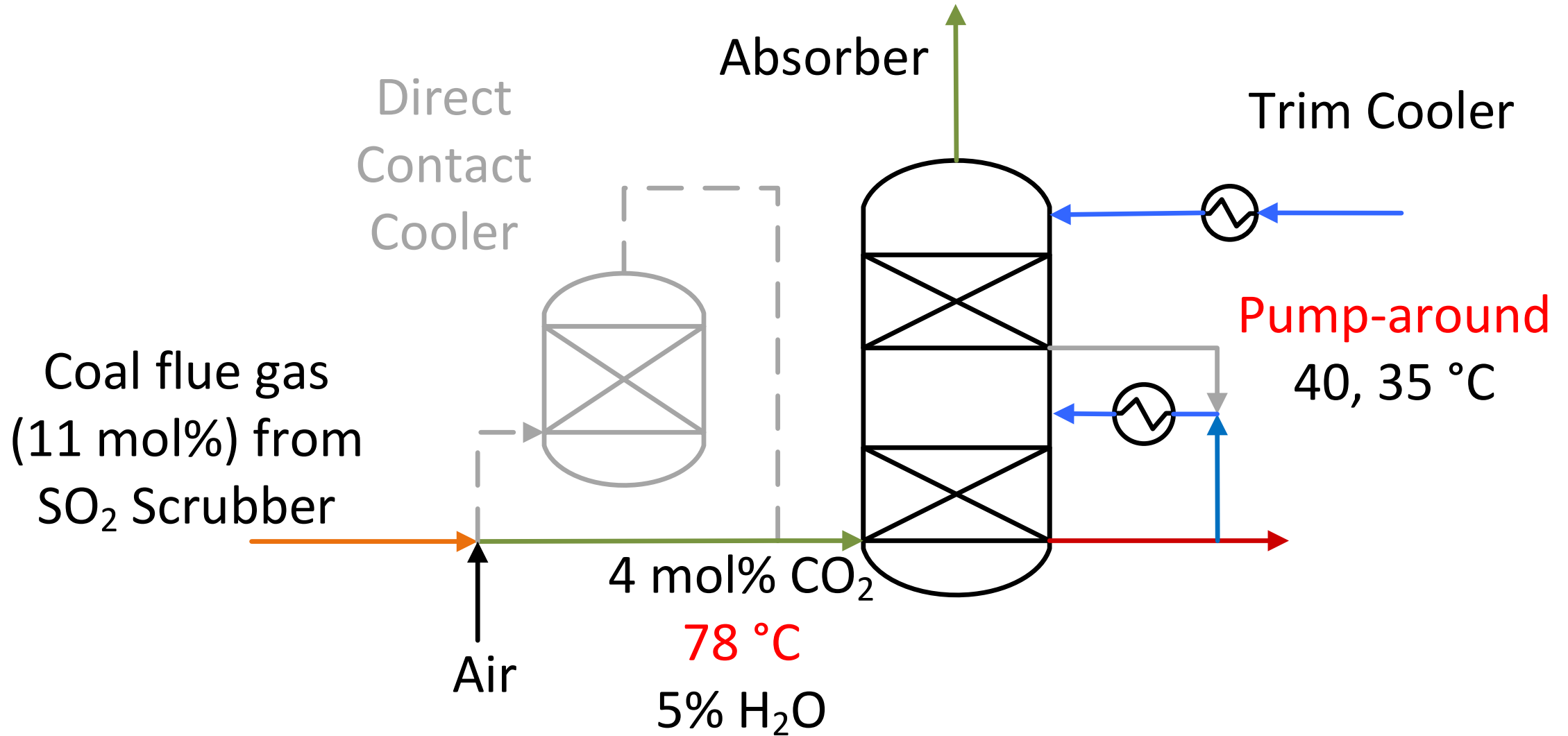
# Aspen model underpredicts heat duty by 10%



# Aspen underpredicts Absorber Transfer Units by 16% with 12% CO<sub>2</sub>



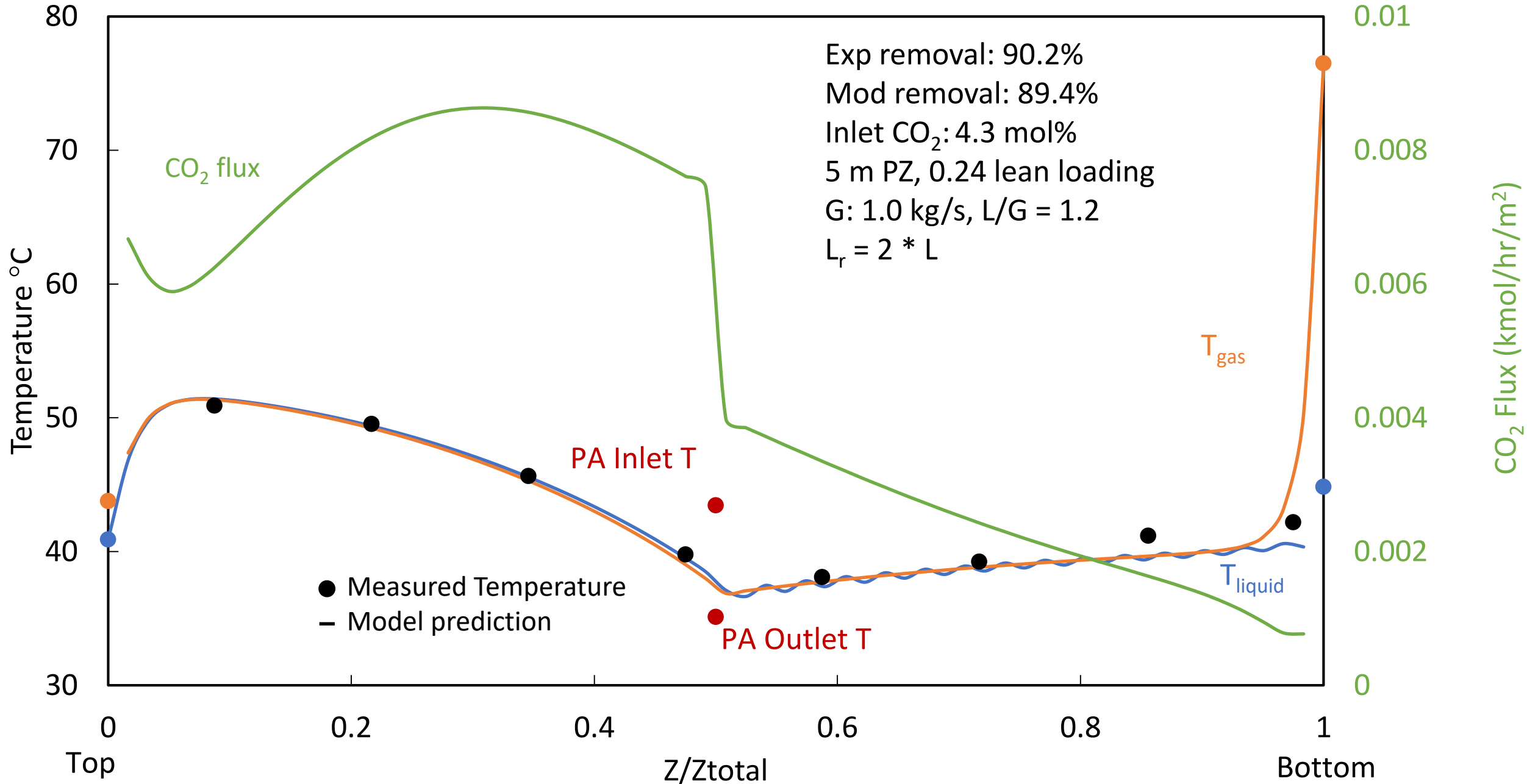
# Pump-around intercooling and no DCC New configuration operated reliably





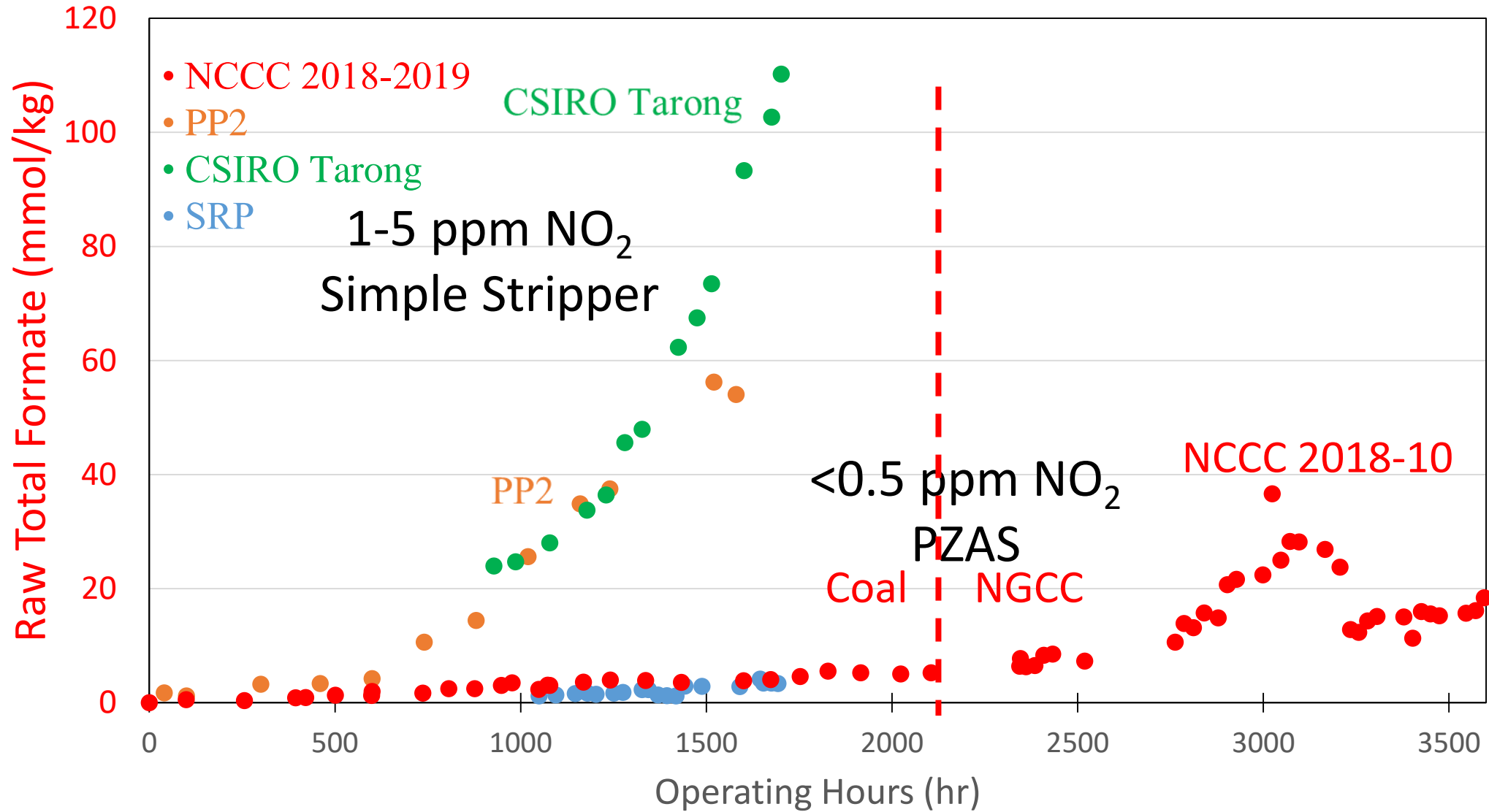


# Aspen predicts T Profile with pump-around Intercooling

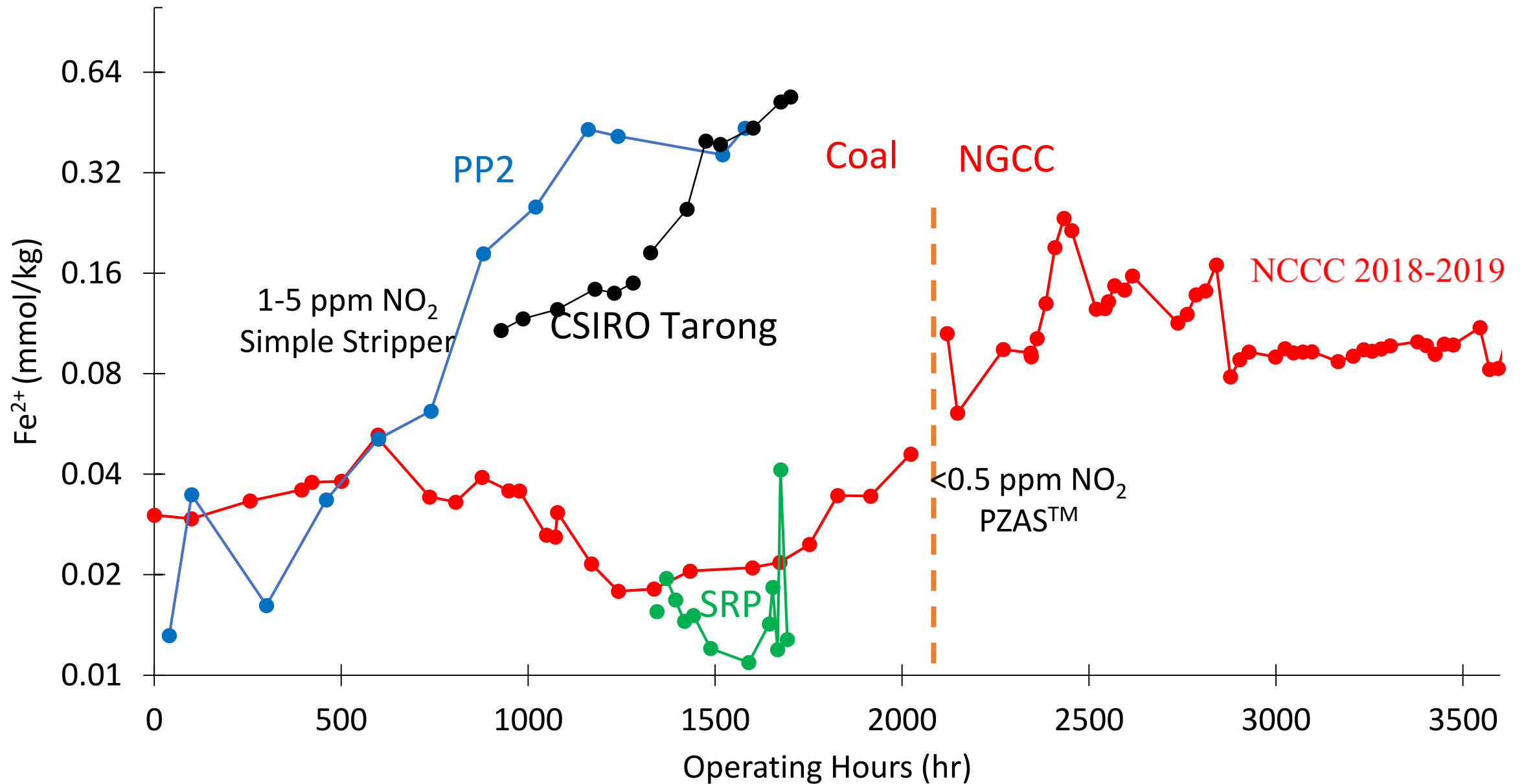


# Amine oxidation: critical results from pilot plants

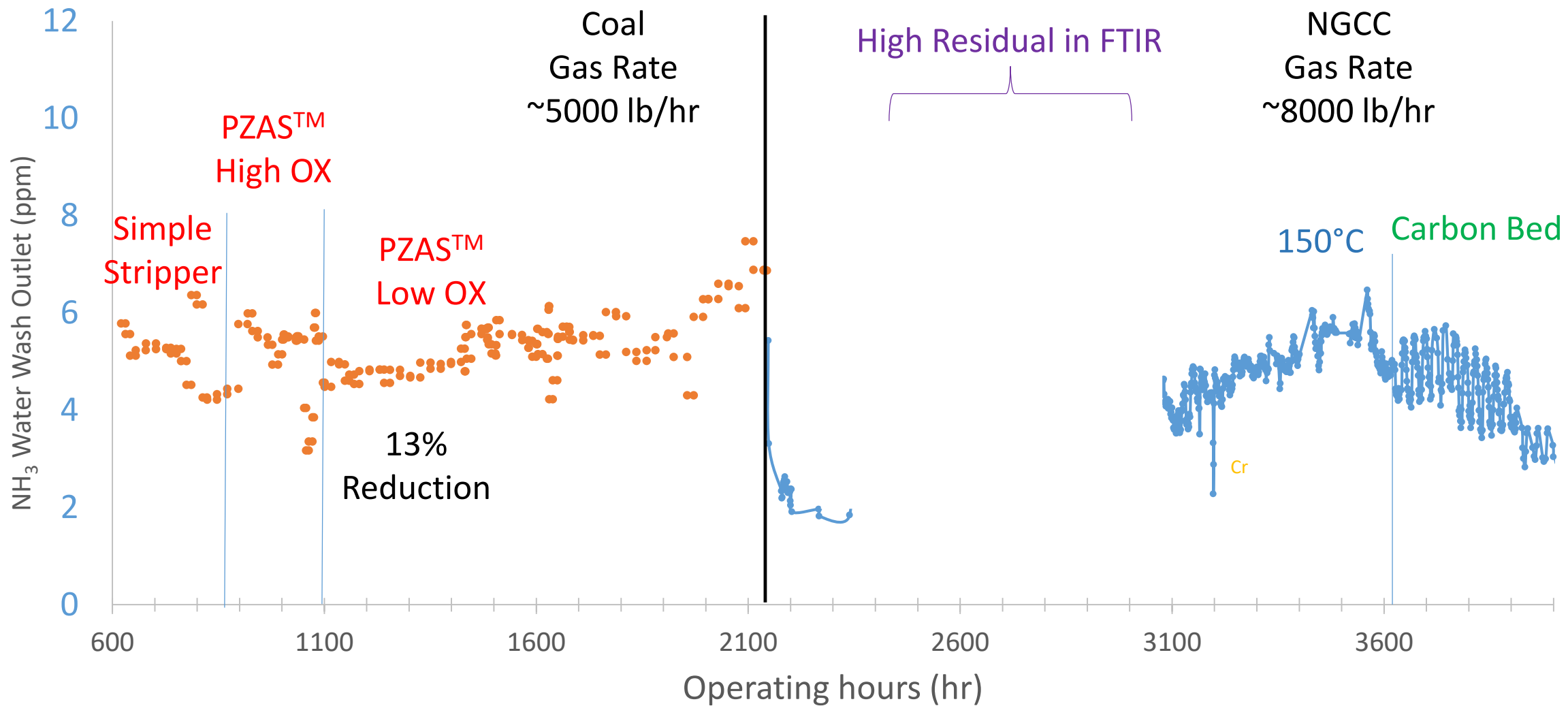
## Less oxidation with lower NO<sub>2</sub>



# Dissolved Fe: Tied to oxidation

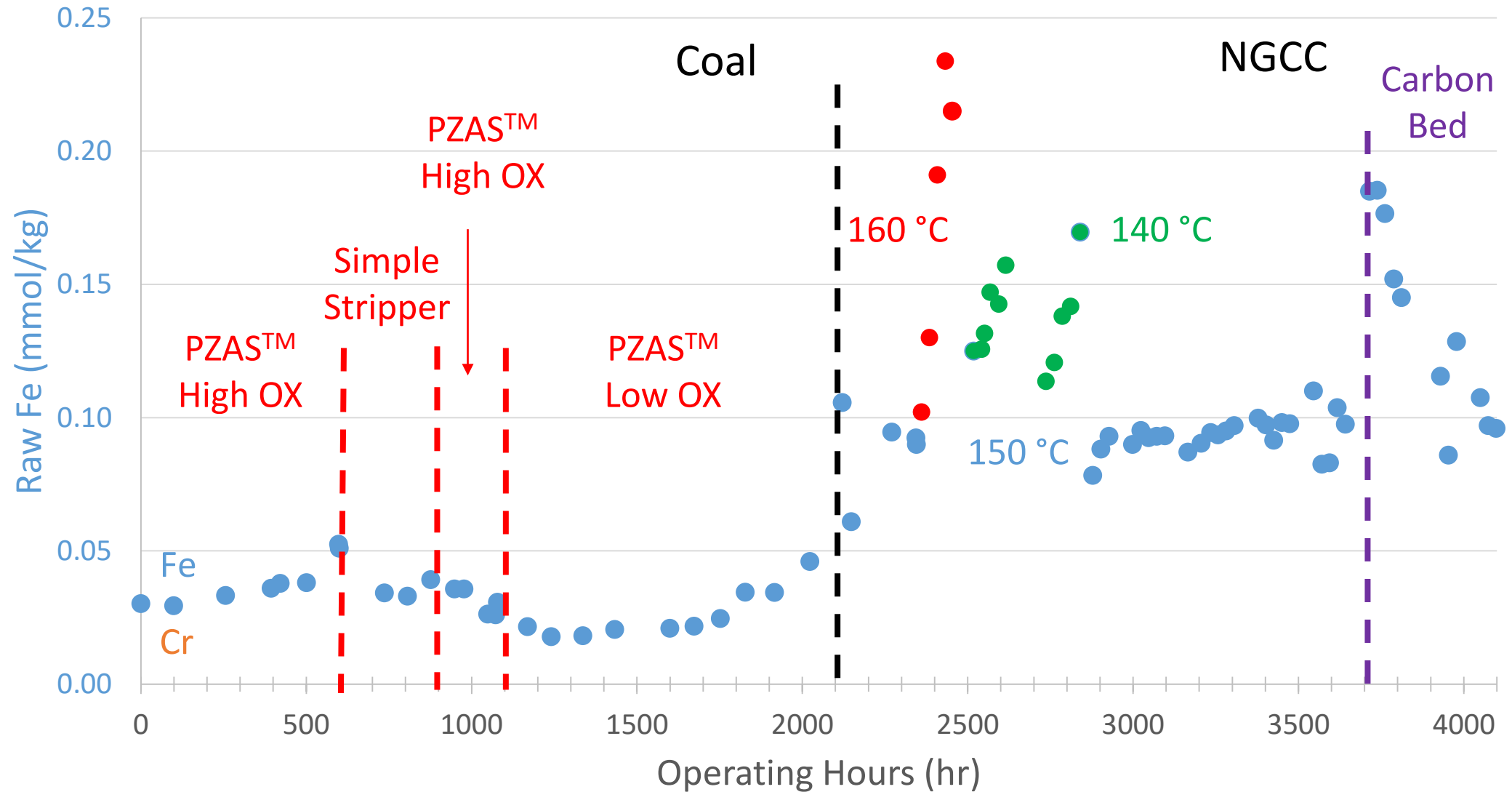


# Carbon Bed Reduces NH<sub>3</sub> Production Rate



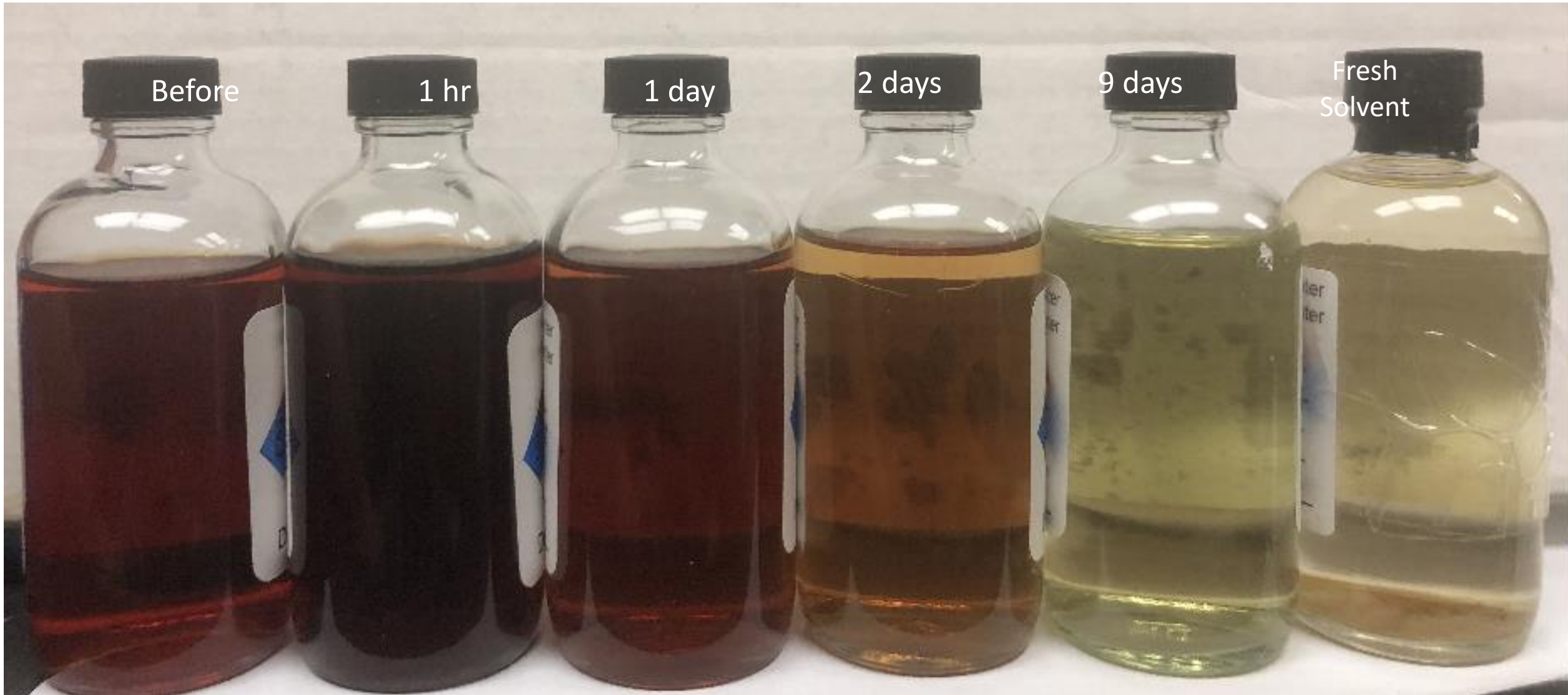
\* NO concentration relatively stable at 50 ppm

# Fe does not decrease w/ use of carbon bed

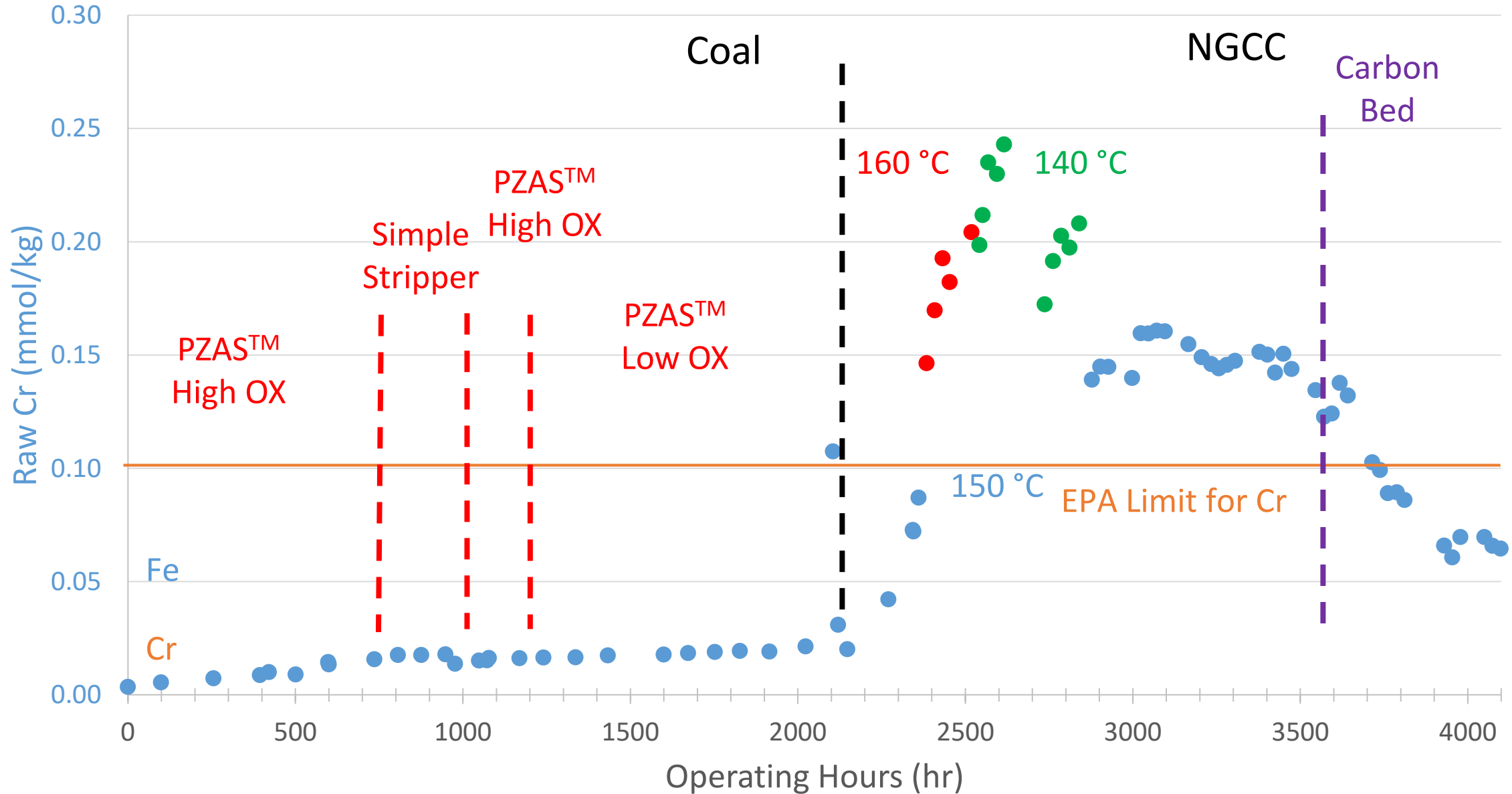


# Carbon Bed removes color

Carbon Bed turned on at 5/14/2019 8:59



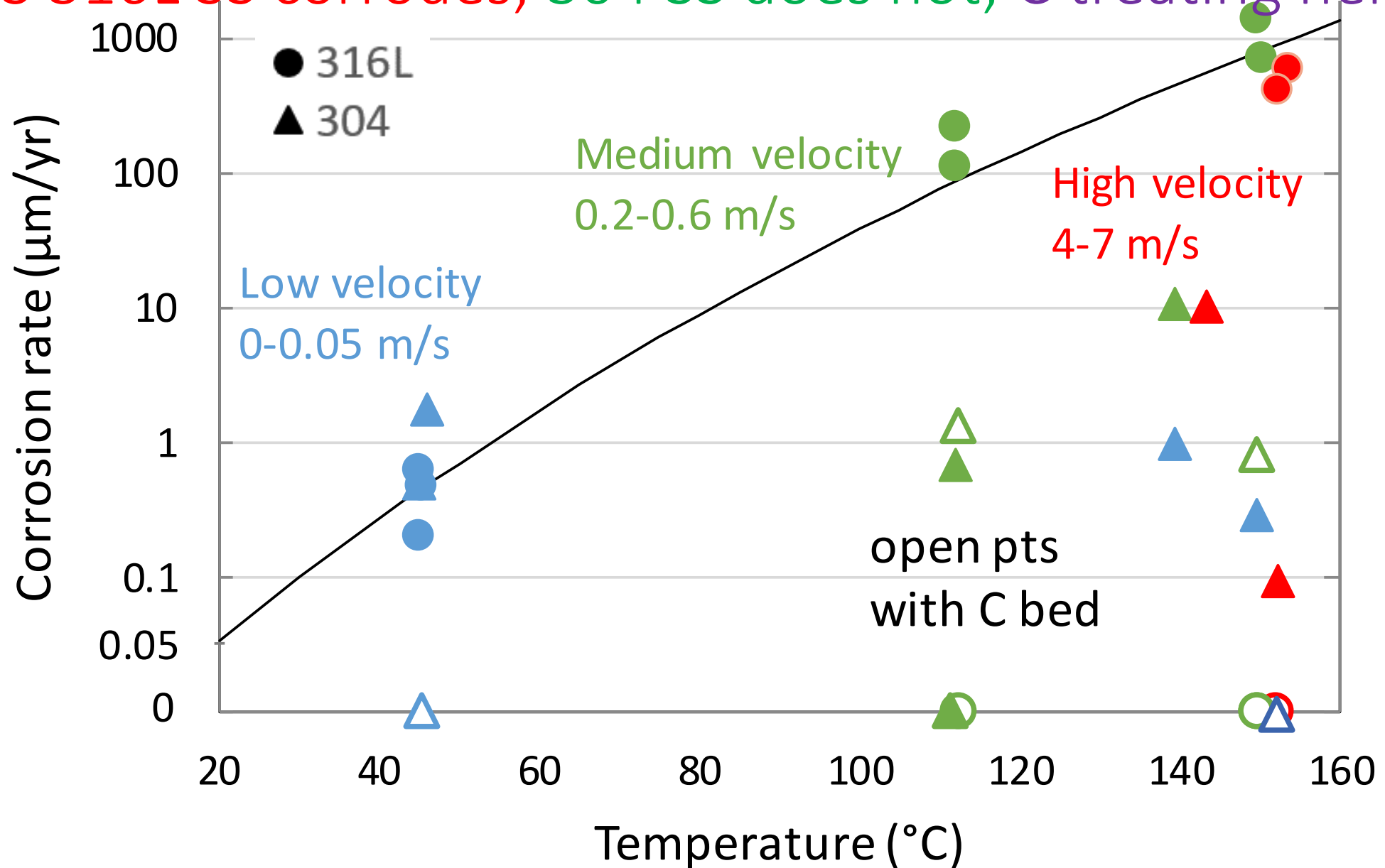
# Carbon Bed Removes Cr



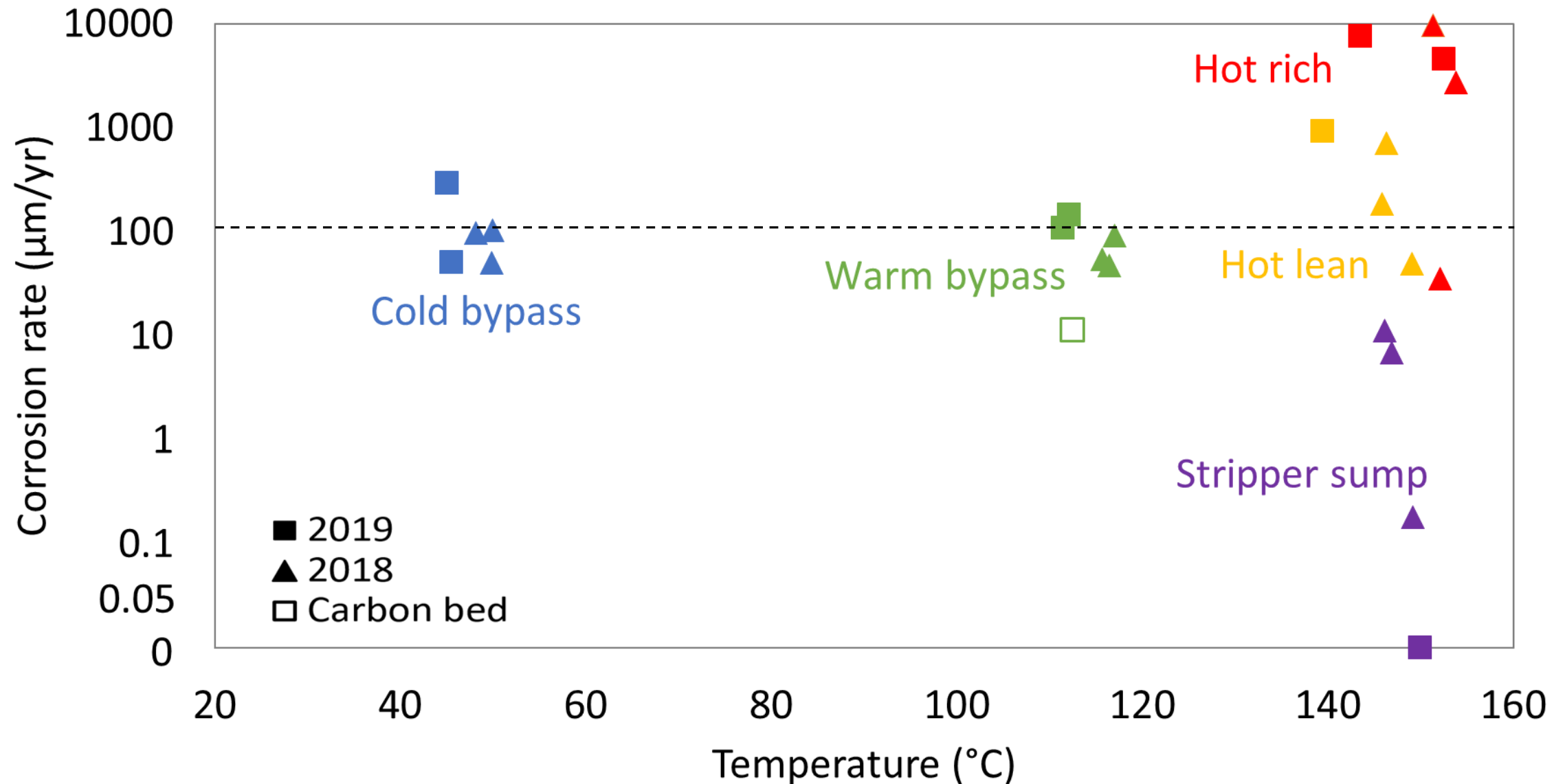


# Pilot testing critical for corrosion results

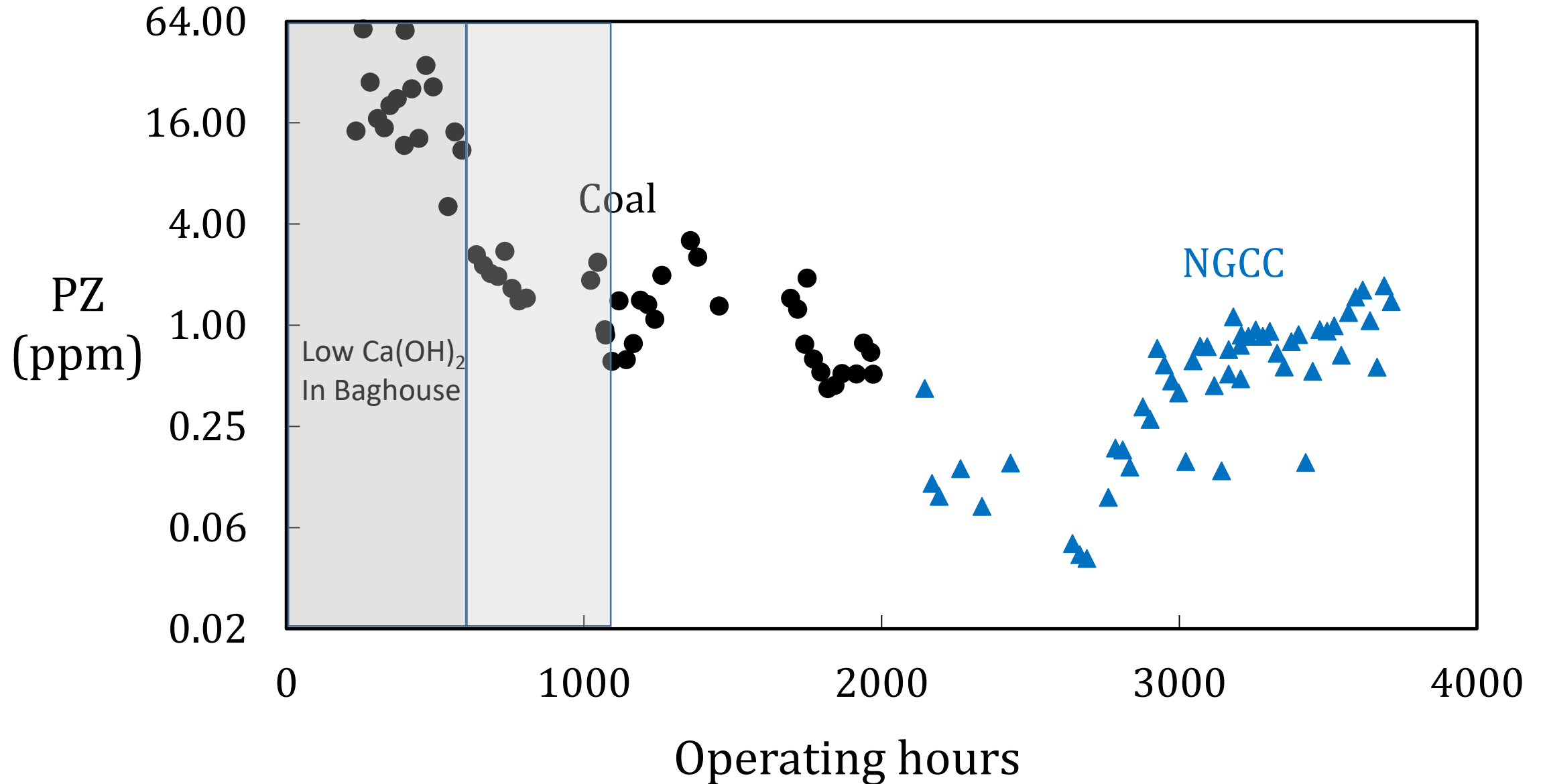
SS 316L SS corrodes; 304 SS does not; C treating helps



# Carbon steel work(s) at lower velocity & lower T



# Pilot demonstrated acceptable PZ Emissions



# PZ Solids Successfully Managed, 2018-19

- PZ.6H<sub>2</sub>O solubility: 2 m w no CO<sub>2</sub>: >5 m w CO<sub>2</sub>
- PZ delivered as 68% solid in mini-ISO container
  - Melted and loaded with CO<sub>2</sub> in circulating hot water
- 8 boiler shutdowns w/o PZ precipitation
  - Solvent gravity drained to rich storage
- Plugged CO<sub>2</sub> product flow meter
  - Once during AFS flooding - Cleaned manually offline
  - Similar plugging with simple stripper (no reflux)

# Conclusions from pilot plant with PZAS™ at NCCC

- Performance models validated
  - $Q = 2.5$  GJ/t w 6 bar stripper, 10% > model
  - 90-95% CO<sub>2</sub> removal with 40 ft packing
    - Model fits when PZ reduced 8%
  - Water wash reduces vapor PZ to < 1 ppm
- New configurations and equipment demonstrated
  - Pump-around intercooling of hot inlet gas
  - Hot, 2-phase Plate & Frame exchangers
  - [Not Compabloc steam heater]

# New Results requiring Pilot plant Operation

- Oxidation
  - Generally Low PZ oxidation,  $<0.3$  lb/t  $\text{CO}_2$  with low  $\text{NO}_2$
- Corrosion
  - 304 SS works well even at  $150^\circ\text{C}$
  - CS might be adequate at lower T and low velocity
  - 316L SS & nickel alloys fail at  $150^\circ\text{C}$
- PZ aerosol emissions
  - Minimized by upstream baghouse that removes  $\text{SO}_3$
- Carbon treating reduces color, oxidation, & corrosion
- Reliable intermittent operation without PZ precipitation

# Acknowledgements

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# Reliability After Start-up

- High reliability for AFS skid
  - Good process stability at wide variety of operating conditions
  - No outages caused by project equipment except CO<sub>2</sub> flow meter plugging
- Equipment other than skid
  - Flue gas blower
    - Vibration tripped at >0.5 MW gas
    - Fixed in 2019
  - Host coal-fired boiler
    - Outages for dispatching
    - Intermittent high NO<sub>x</sub> & SO<sub>3</sub>