Amine Aerosol Characterization by FTIR and PDI in Pilot Plant Testing

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THE UNIVERSITY OF TEXAS AT AUSTIN
McKetta Department of Chemical Engineering
Cockrell School
TxCCMP

Outline

Introduction

- Amine scrubbing
- Aerosol emissions

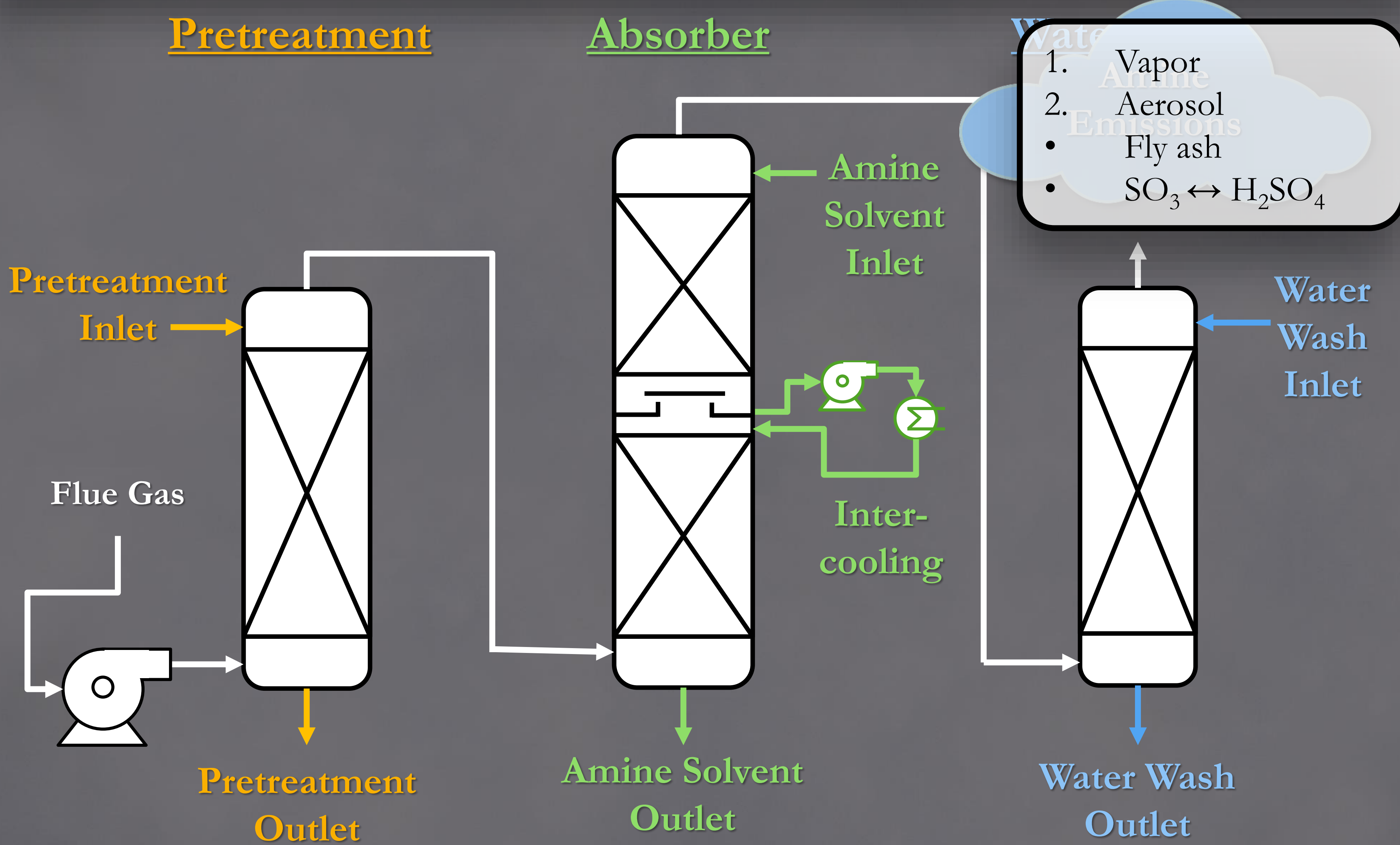
Analytical Methods

- Fourier Transform Infrared Spectrometry
- Phase Doppler Interferometry

Results

- Baghouse Pretreatment at NCCC
- SO_3 Generation at UT-SRP
- SO_3 Concentration Effect on Aerosol Emissions
- WW Temp and Flows
- Generalized Aerosol Emission Correlations

Introduction: Amine-Based CO_2 Capture



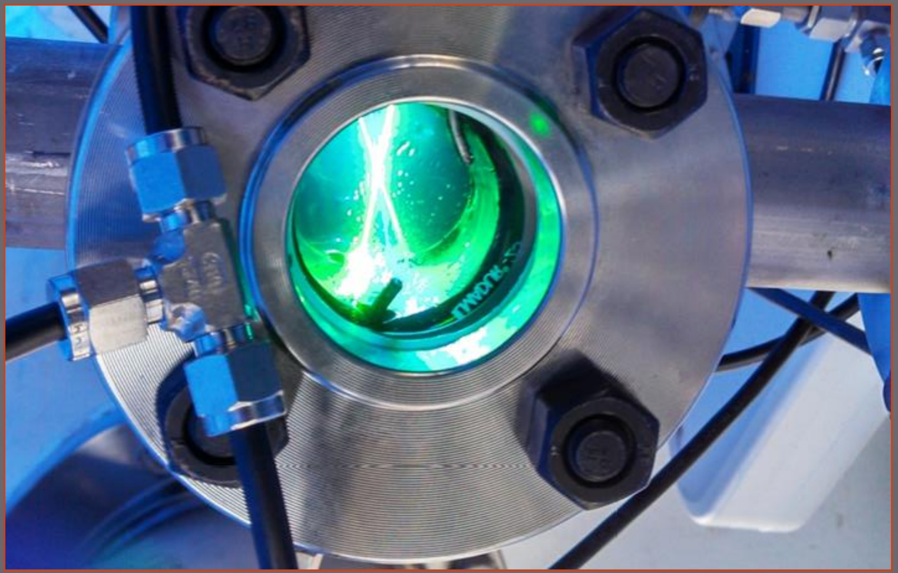
Analytical Methods

FTIR

- Gasmet DX-4000
- Concentrations of H_2O, CO_2, NH_3, SO_2, Amines
- No differentiating between vapor and aerosol phases

PDI

- Artium Technologies
- Drop sizes 0.1 to 12 μm
- Concentrations up to 10^7 per cm^3



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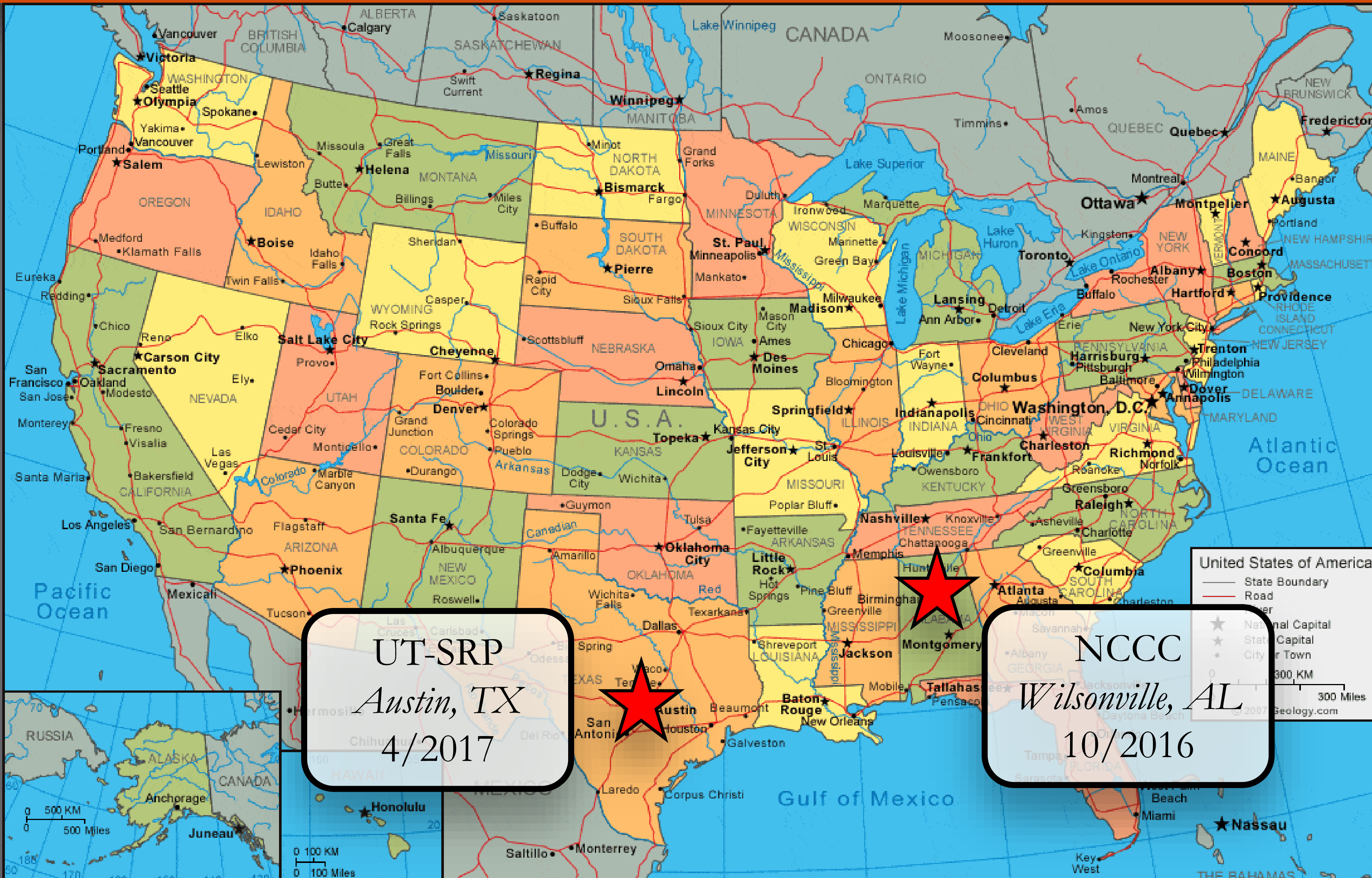
Amine Scrubbing Pilot Plant Sampling



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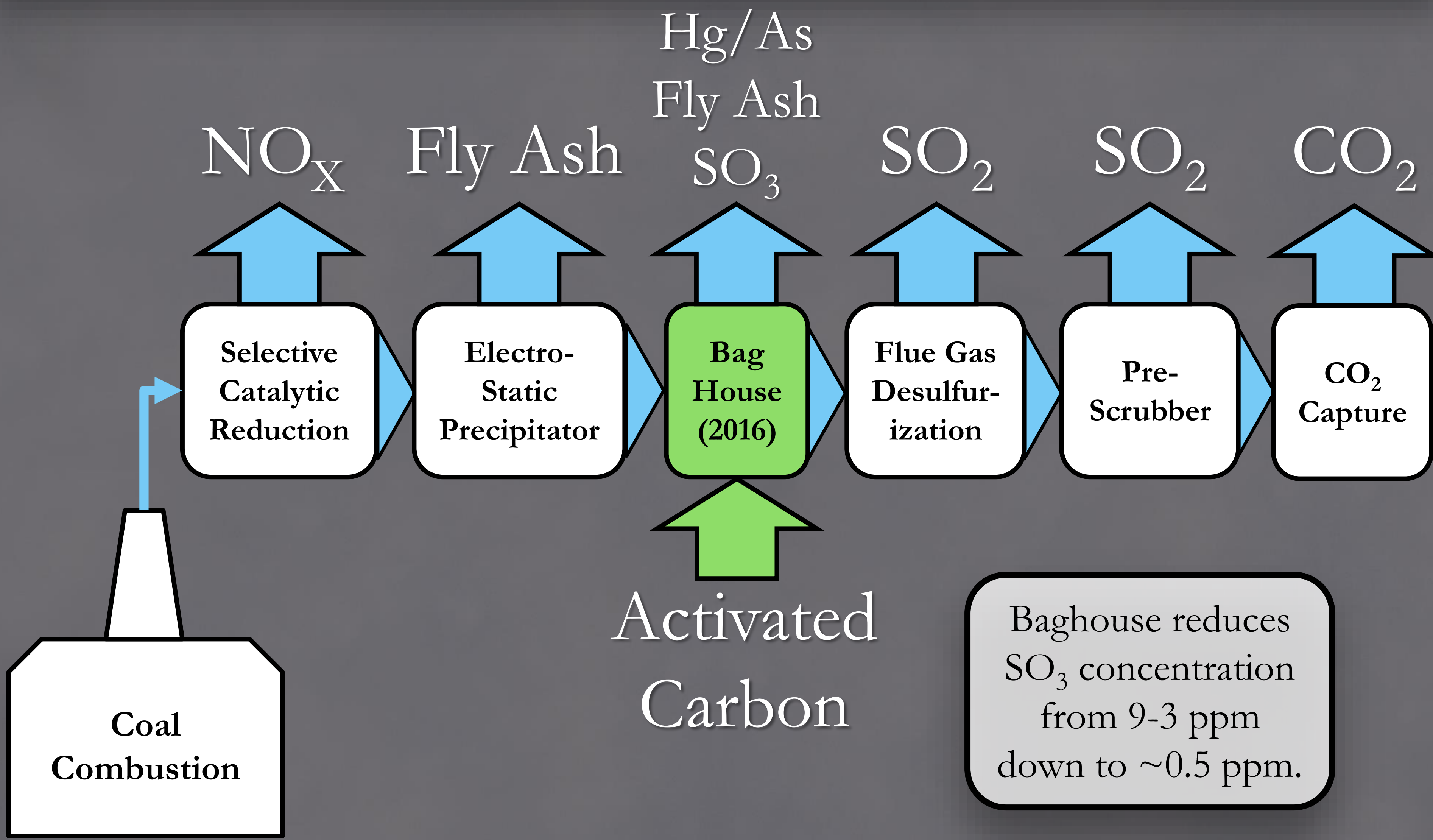
Upstream Baghouse Flue Gas Treatment



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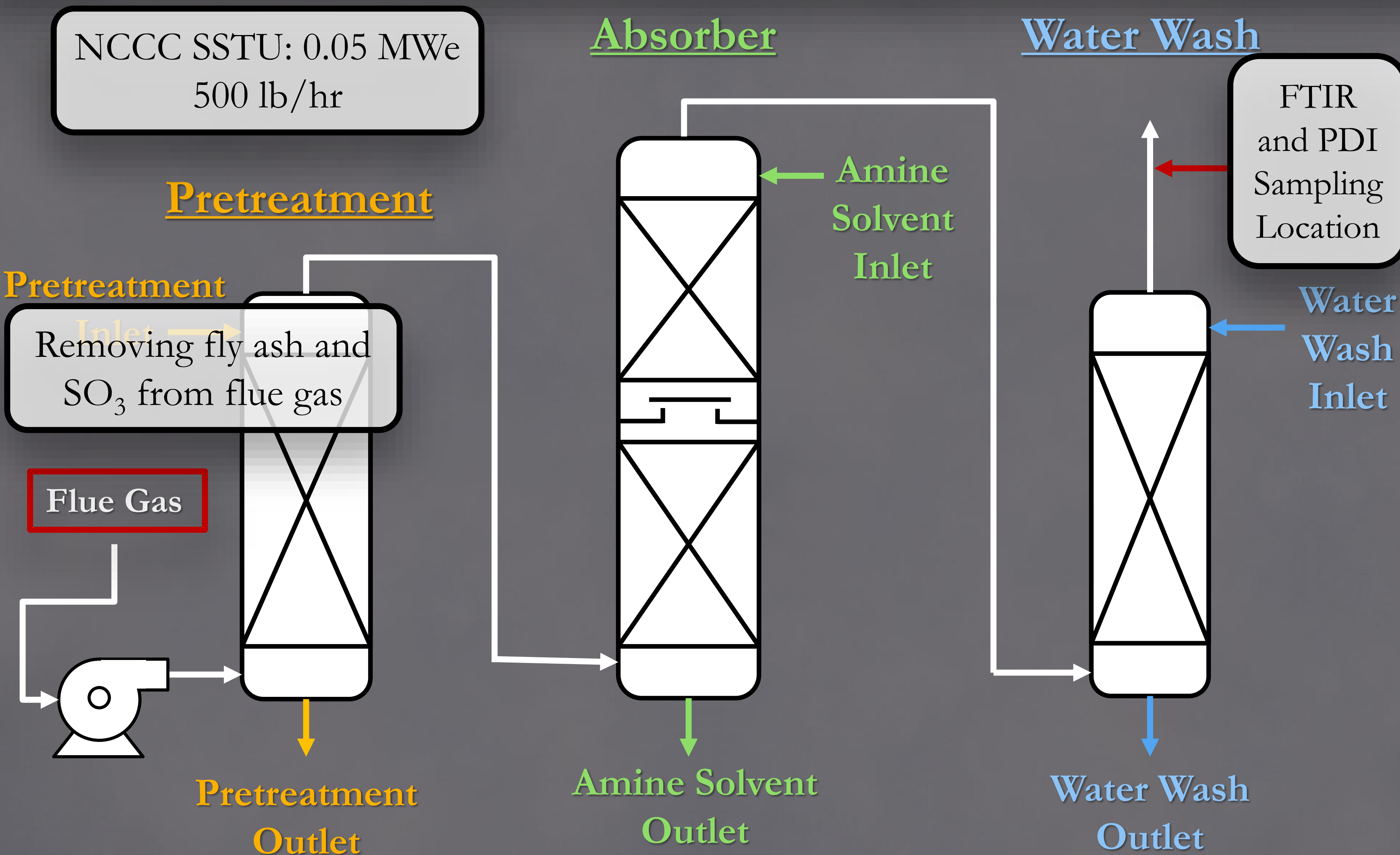

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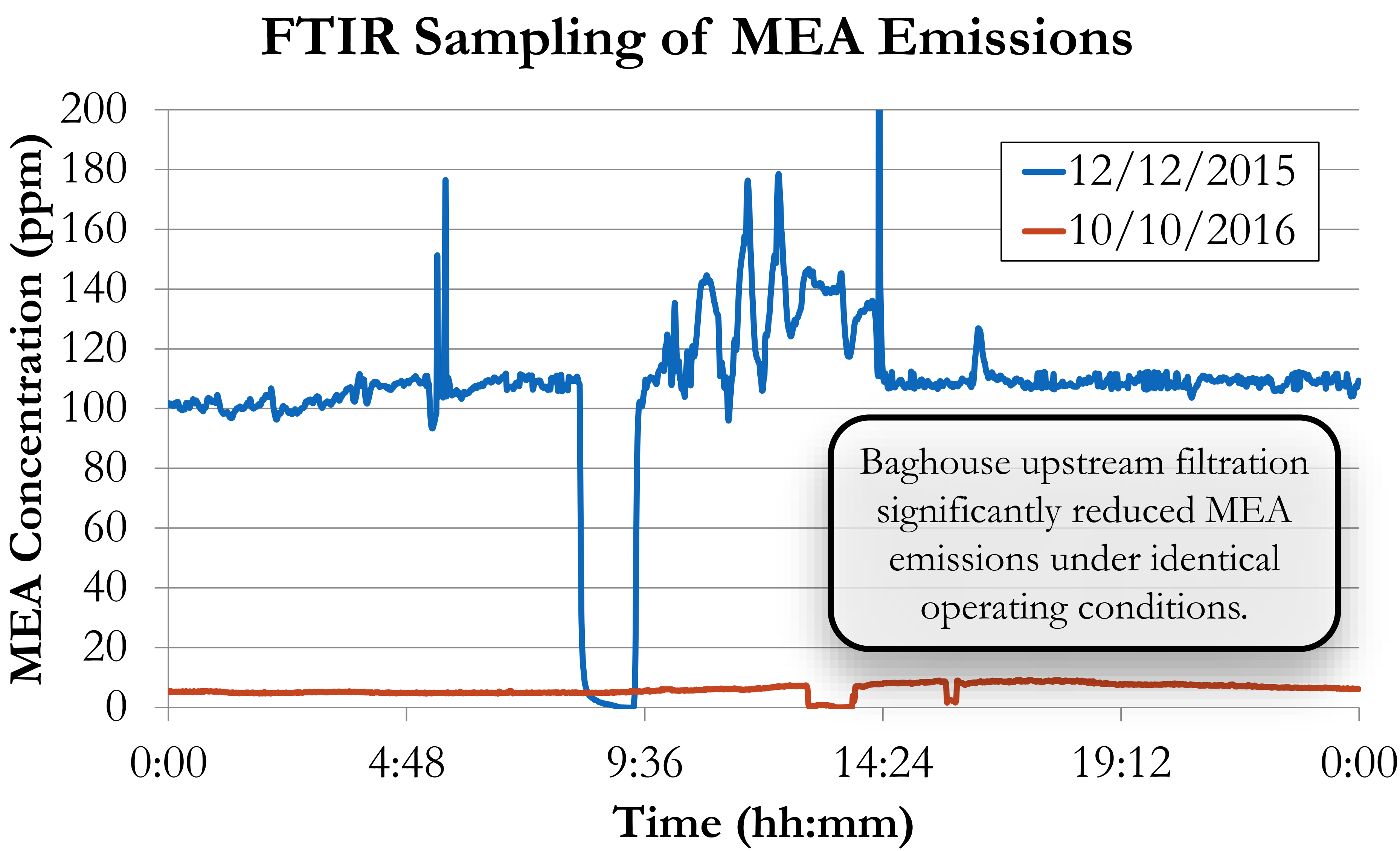
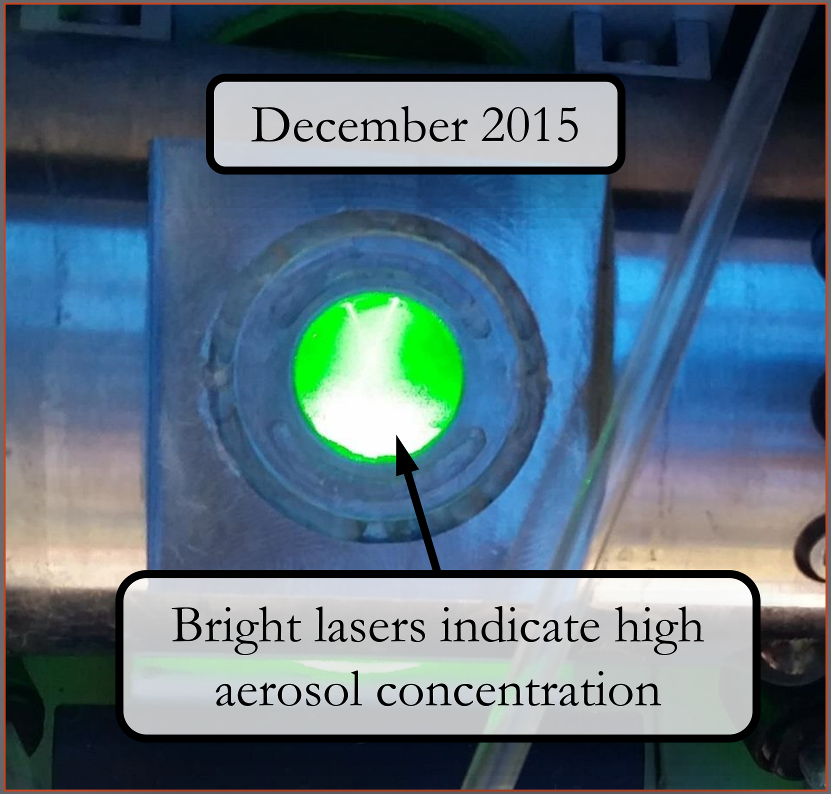


Upstream Baghouse Flue Gas Treatment

PDI measurements on SSTU outlet:



Unable to detect aerosol at water wash outlet (<0.1 µm diameter & low concentration)

SO_3 Generation at UT-SRP

Baghouse is effective at aerosol mitigation

- Expensive solution
  - Will not be constructed at every facility
- Still need to improve understanding of how amine scrubbing process conditions impact aerosol emissions.

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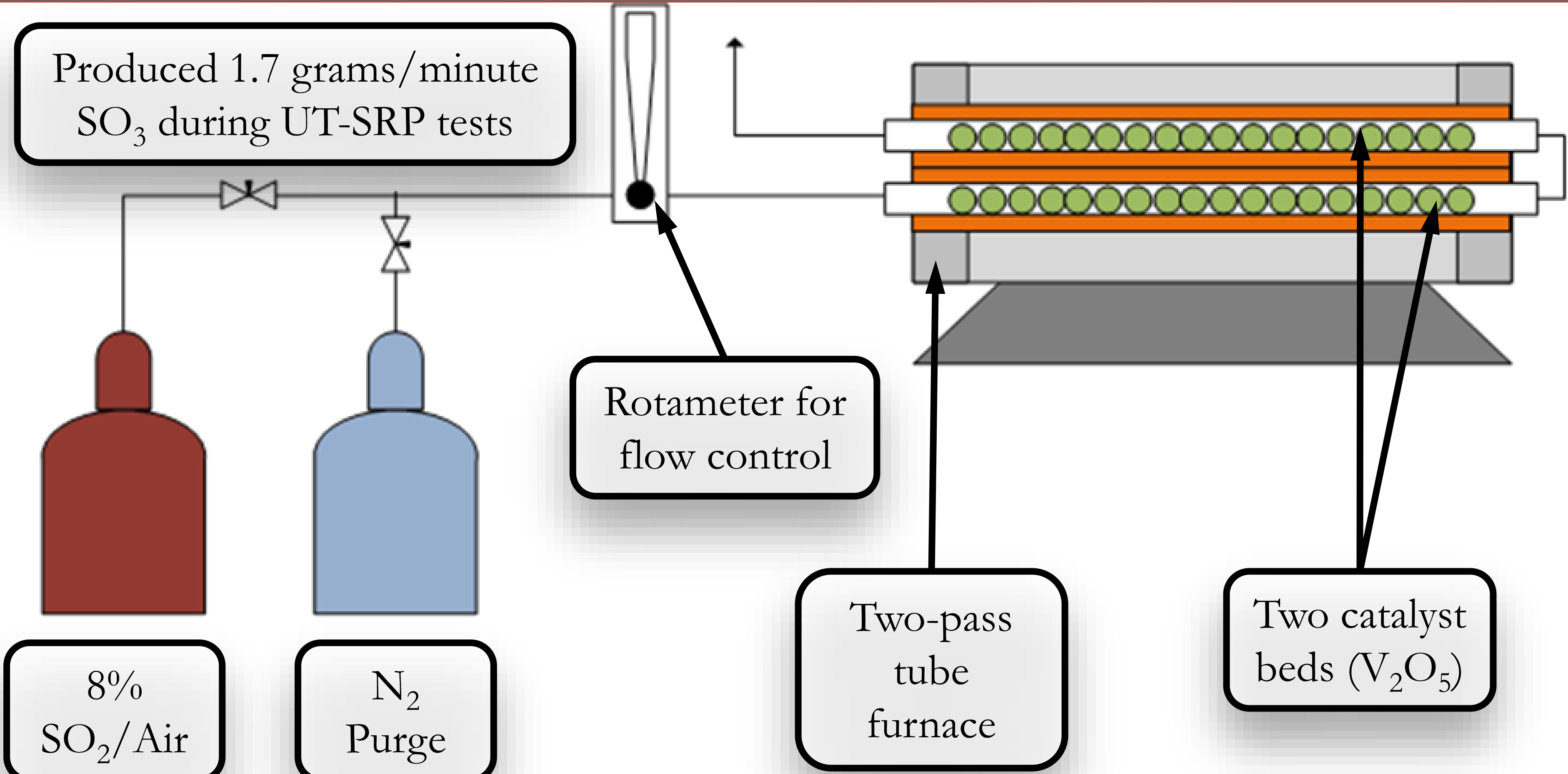
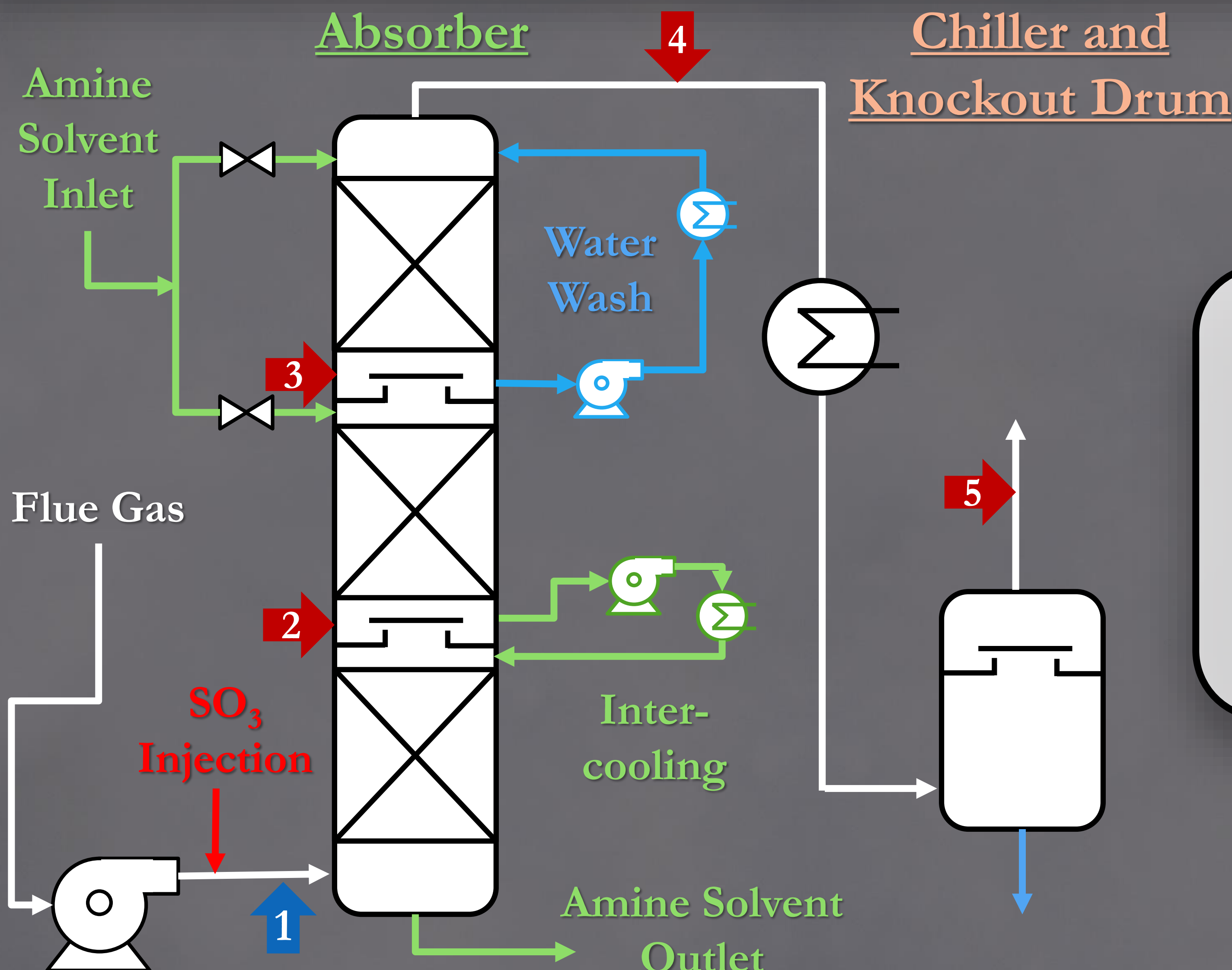
SO_3 Generation at UT-SRP

$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$$

Produced 1.7 grams/minute SO_3 during UT-SRP tests

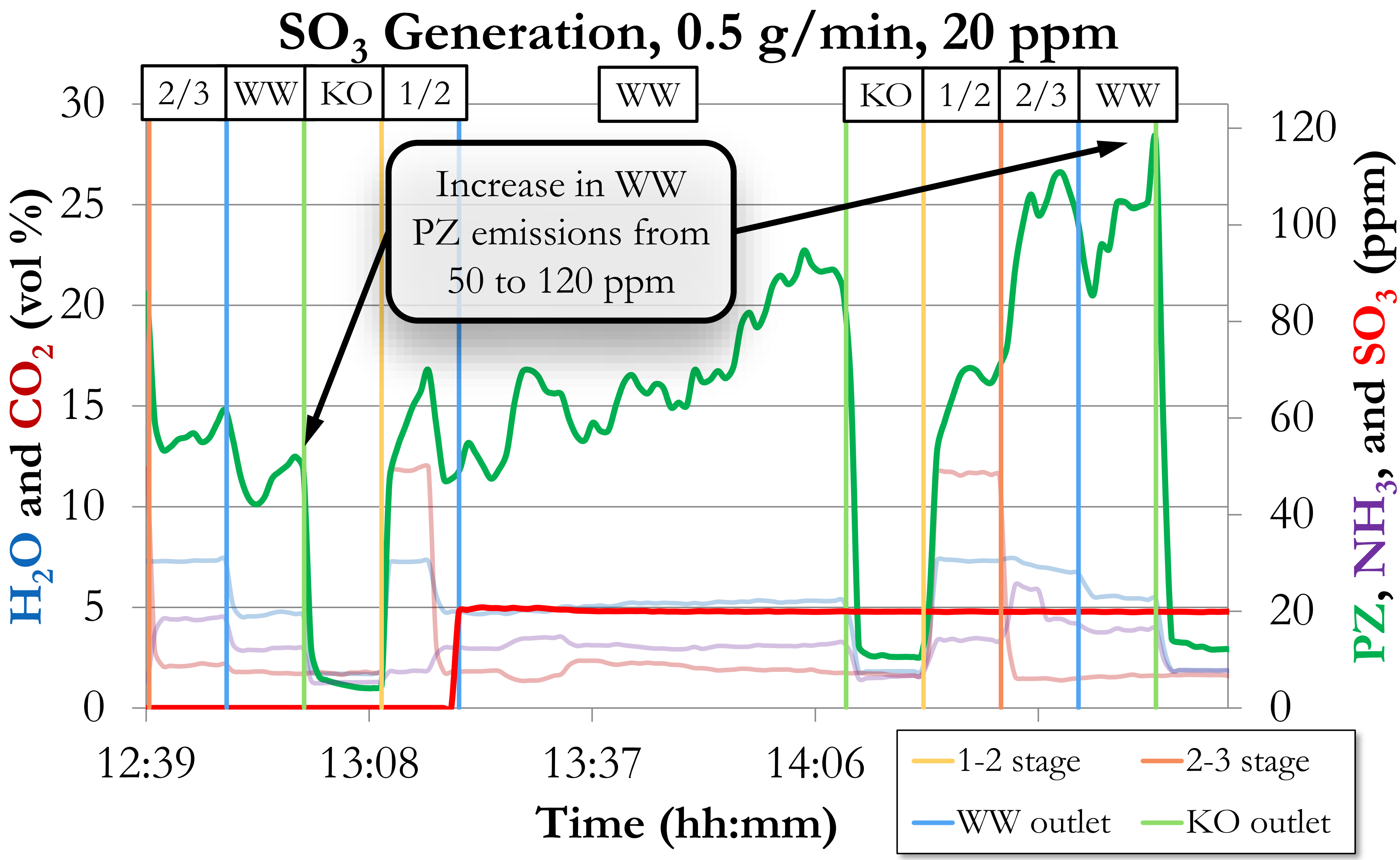


UT-SRP Pilot Plant: 0.1 MWe



5 Point FTIR Sampling system:
(1) Inlet
(2) 1/2 Stage
(3) 2/3 Stage
(4) Outlet
(5) KO Outlet

SO_3 Generation and PZ Emissions



SO_3 Generation and PZ Emissions

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SO_3 Generation and PZ Emissions

	Average	Min	Max
SO_3 Concentration (ppm)	41	9	112
SO_3 Generated (g/min)	0.84	0.23	1.68
SO_3 Conversion Rate (%)	93.5	81.3	98.1
WW PZ Emissions with SO_3 Injection	90	9	189
ppm PZ emitted per ppm SO_3 injected	1.50	0.00	7.56

- 224 ppm for NCCC SSTU (0.05 MWe)
- 112 ppm for UT-SRP (0.1 MWe)
- 22 ppm for NCCC PSTU (0.5 MWe)

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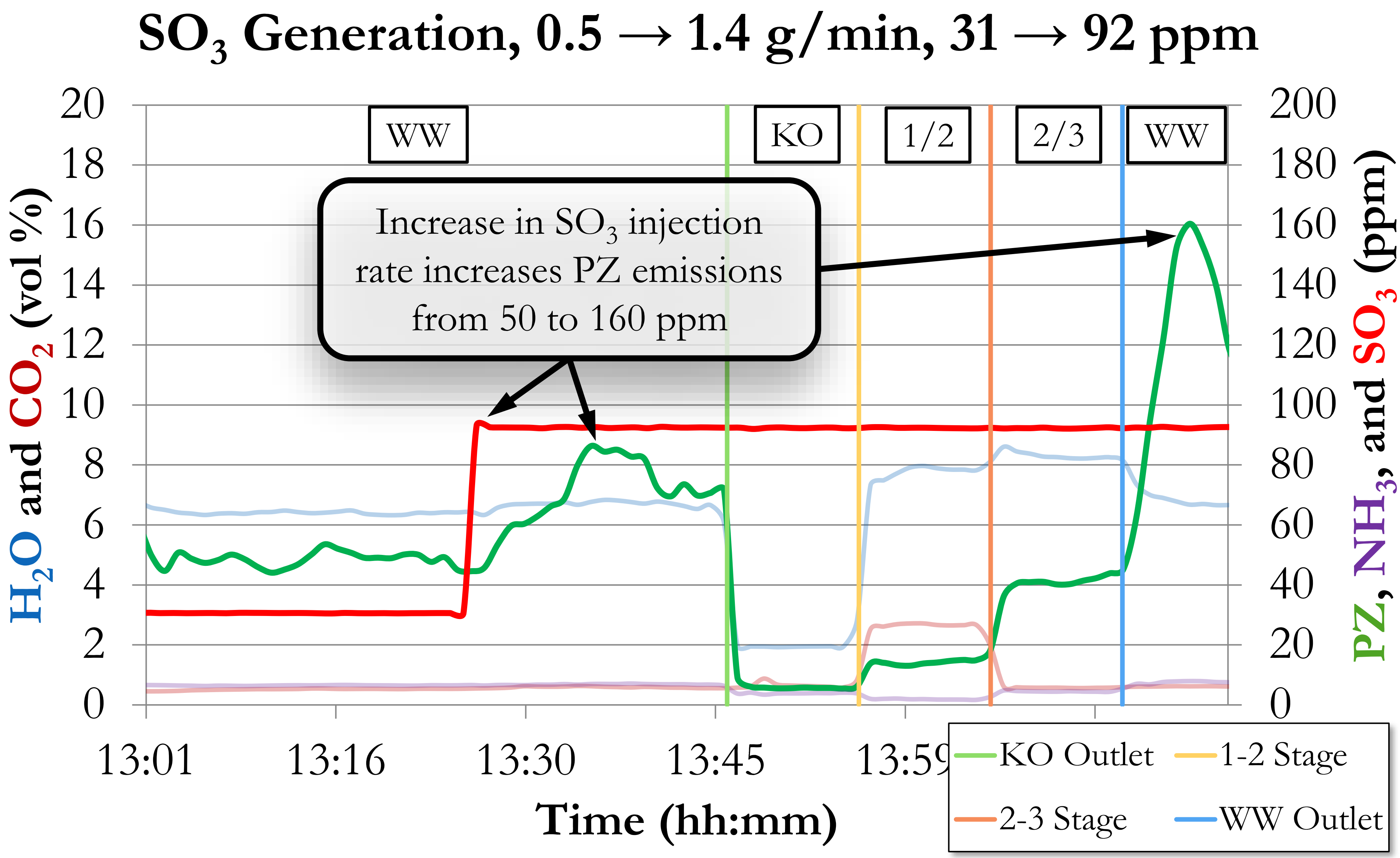
Water Wash Effect on PZ Emissions



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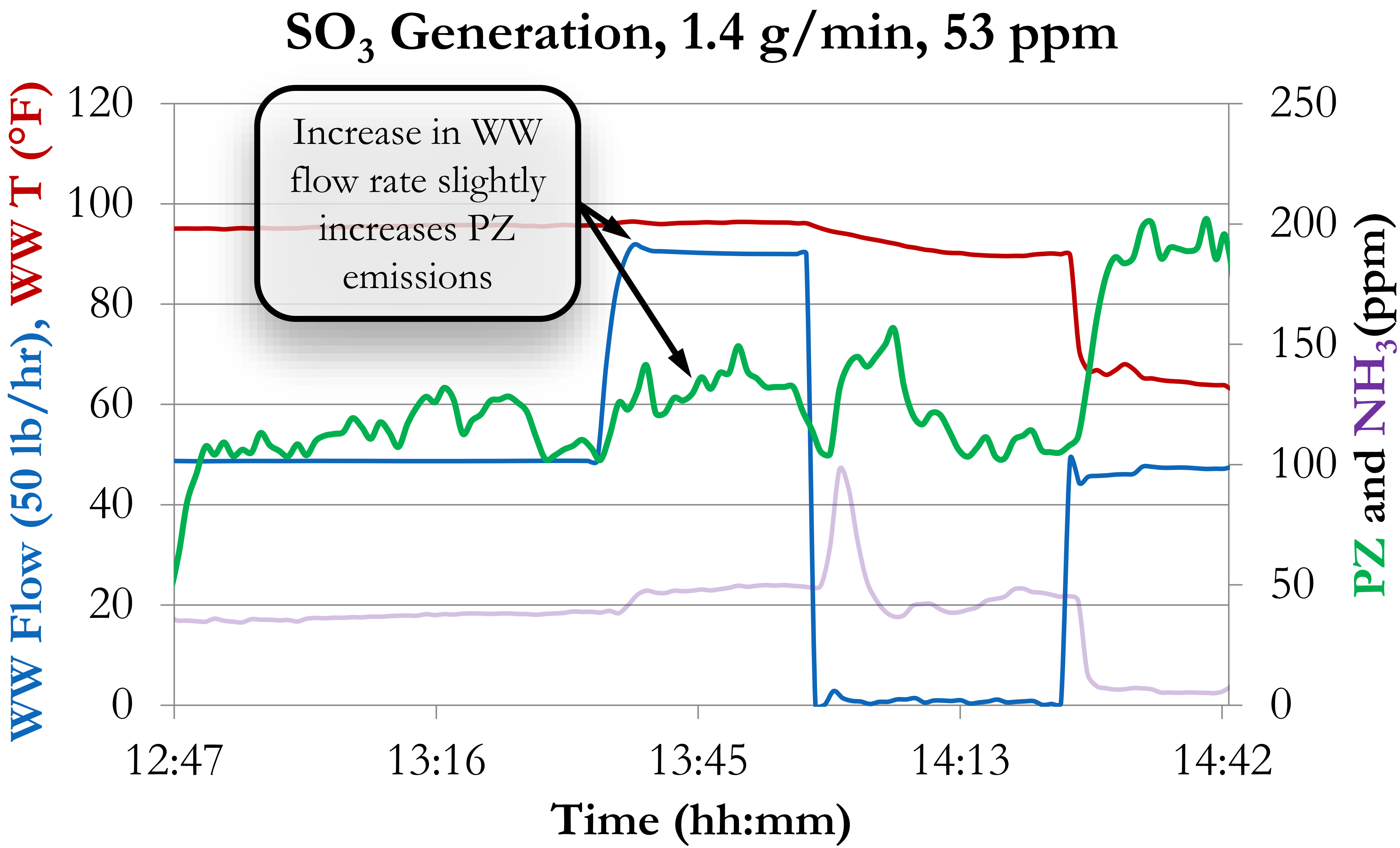
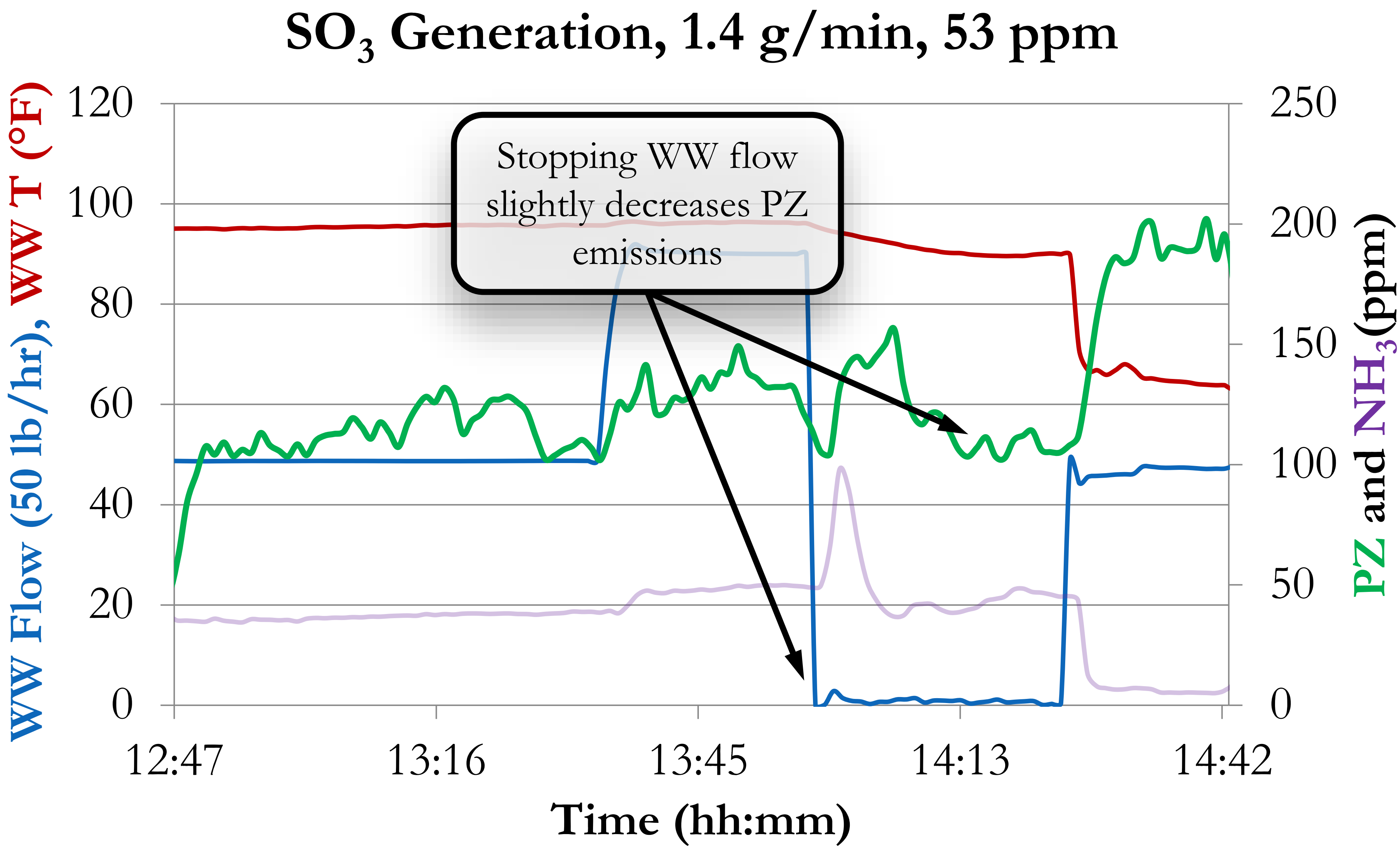


Water Wash Effect on PZ Emissions



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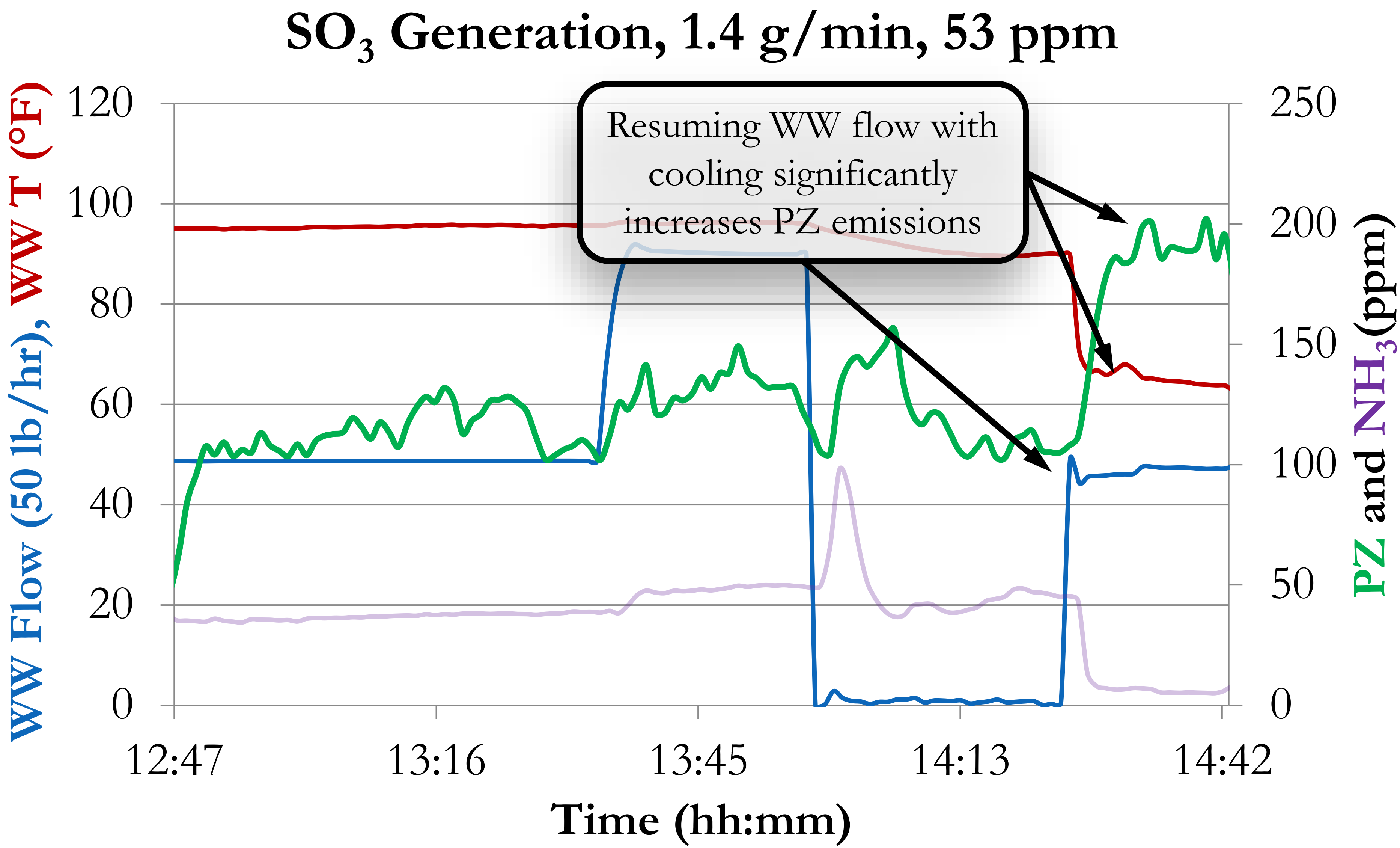
Water Wash Effect on PZ Emissions



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Aerosol Emission Correlations

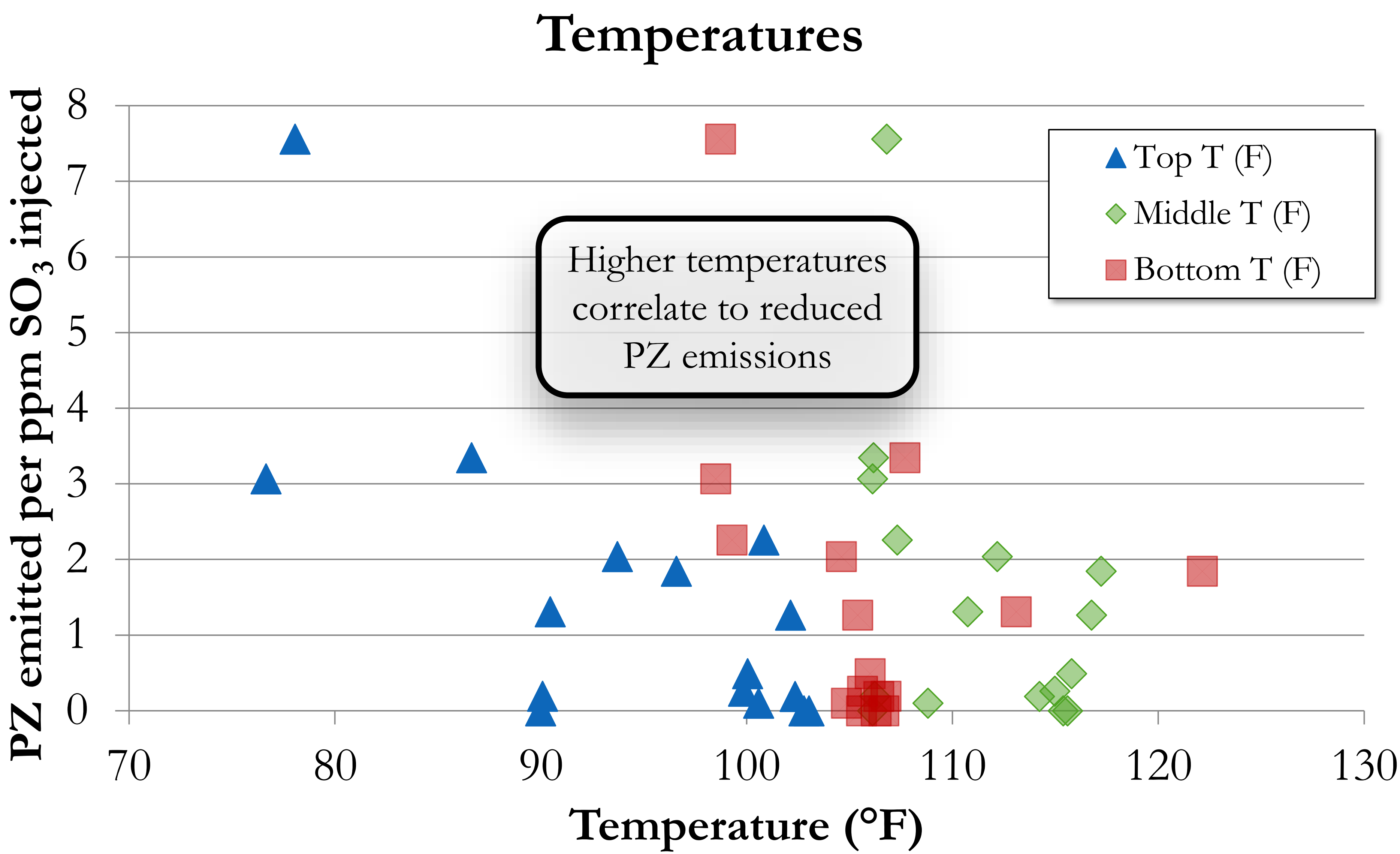
- Analysis of process properties to observe how each impacts aerosol emissions:
  - Temperatures
  - Flow Rates
  - Gas Phase Concentrations

Aerosol Emission Correlations

Temperatures:	R^2
Gas Outlet T	0.564
Top Solvent/WW T	0.493
IC Solvent T	0.118
Top Bed T	0.510
Middle Bed T	0.172
Bottom Bed T	0.107

- Temperatures at top bed have greater correlation with amine emissions than lower bed temperatures.
- Amine emissions depend on gas temperatures more than solvent temperatures.

Aerosol Emission Correlations



Aerosol Emission Correlations

Flow Rates	R^2
Water Wash Flow	0.397
Intercooling Flow	0.206
L/G	0.162

- Solvent flow rates at top beds have a greater impact on amine emissions than flow rates through lower beds

Aerosol Emission Correlations

Gas Phase Concentrations	R^2
CO_2 In	0.143
CO_2 Out	0.270

- CO_2 concentration at absorber outlet has greater correlation with amine emissions than CO_2 concentration at inlet

Conclusions

- Baghouse pretreatment mitigates amine aerosol at NCCC.
- Increasing SO_3 concentrations increases amine emissions.
- Process temperatures most significant in determining aerosol emissions.
  - Gas temperatures matter more than solvent temperatures.
  - Temperatures at absorber outlet more significant than temperatures at the inlet.
- Solvent emissions more dependent on water wash flow rates than intercooling/lower bed flow rates.
- Increasing CO_2 concentration at absorber outlet decreases amine aerosol emissions.

Acknowledgements

Thank you

- Rochelle Lab
  - Dr. Rochelle
  - Dr. Steven Fulk
  - Dr. Eric Chen
  - Korede Akinpelumi and Vietnam Nguyen
- NCCC SSTU operations crew
- UT-SRP operations crew

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Mertens J, Knudsen J, Thielens ML, Anderson J. "On-line monitoring and controlling emissions in amine post combustion carbon capture: A field test" *Int. J. Greenhouse Gas Control*. 2012;6:2-11.

Saha C., Irvin J. H. "Real-time aerosol measurements in pilot scale coal fired post-combustion CO2 Capture." *Journal of Aerosol Science*. 2017;104:43-57

Additional Slides

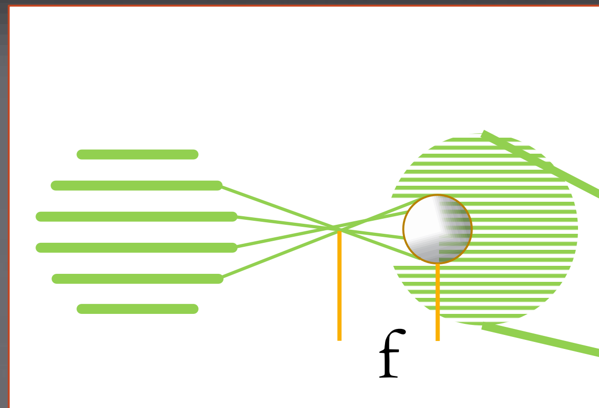
Analytical Methods: PDI

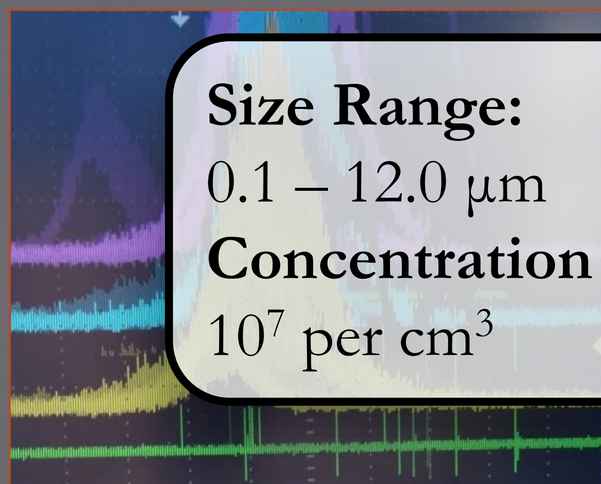
Photodetectors quantify drop size via phase shift

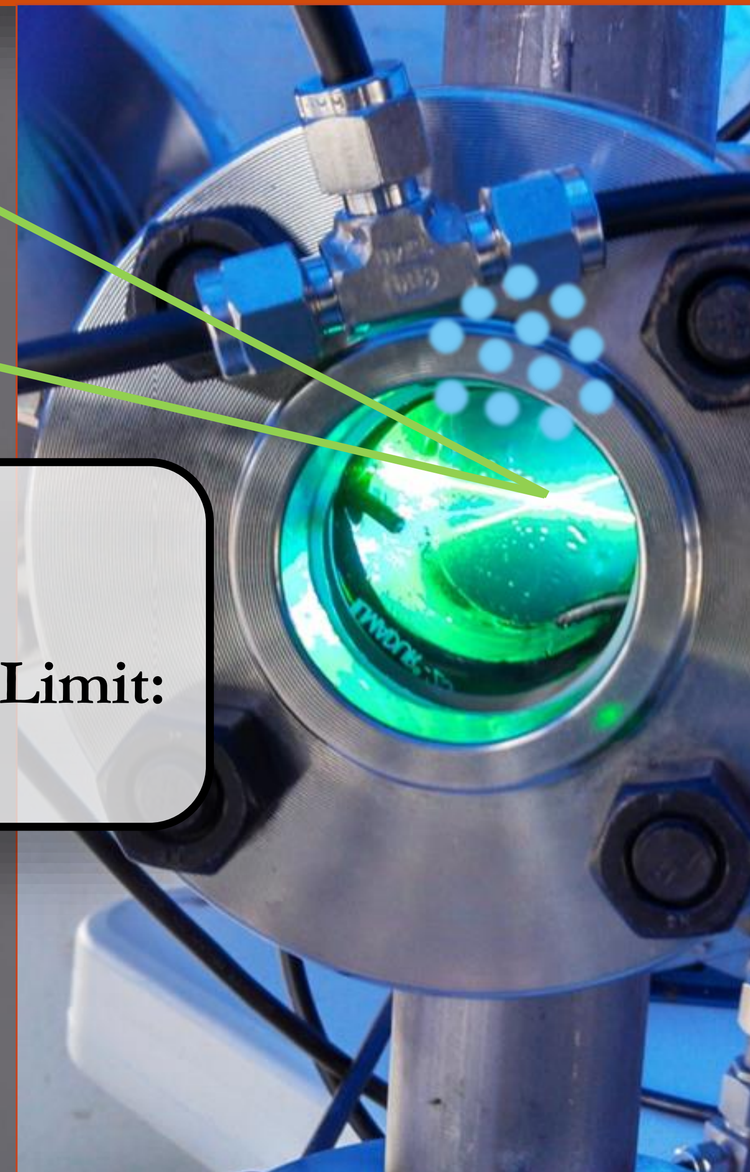
- Reduces window attenuation

Droplet movement causes Doppler shift in phases

- Determines droplet velocity







Size Range:
0.1 – 12.0 µm
Concentration Limit:
10^7 per cm^3

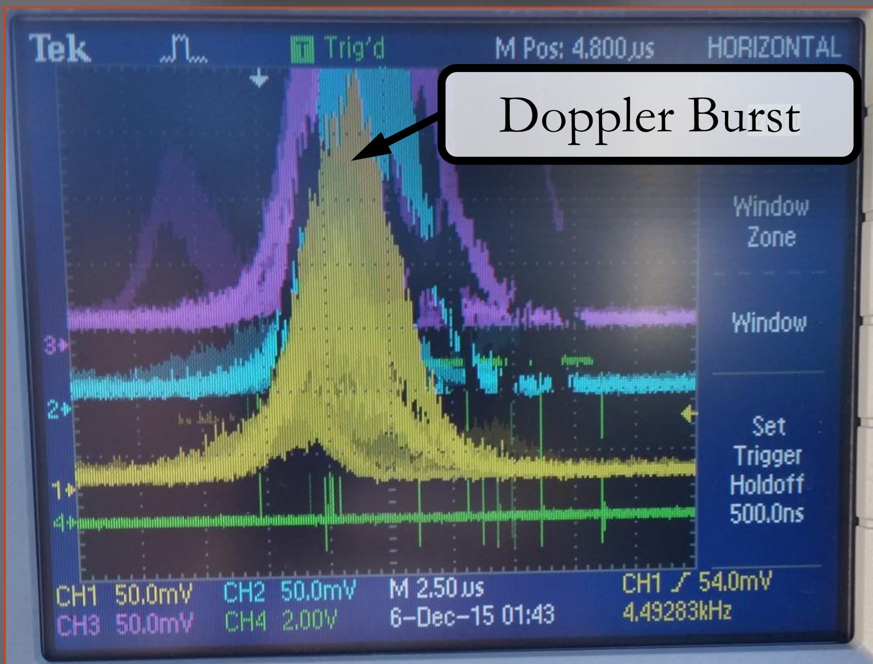
Velocity + number count used to determine particle concentration

Artium Technologies, *PDI-100MD User Manual,* 2015

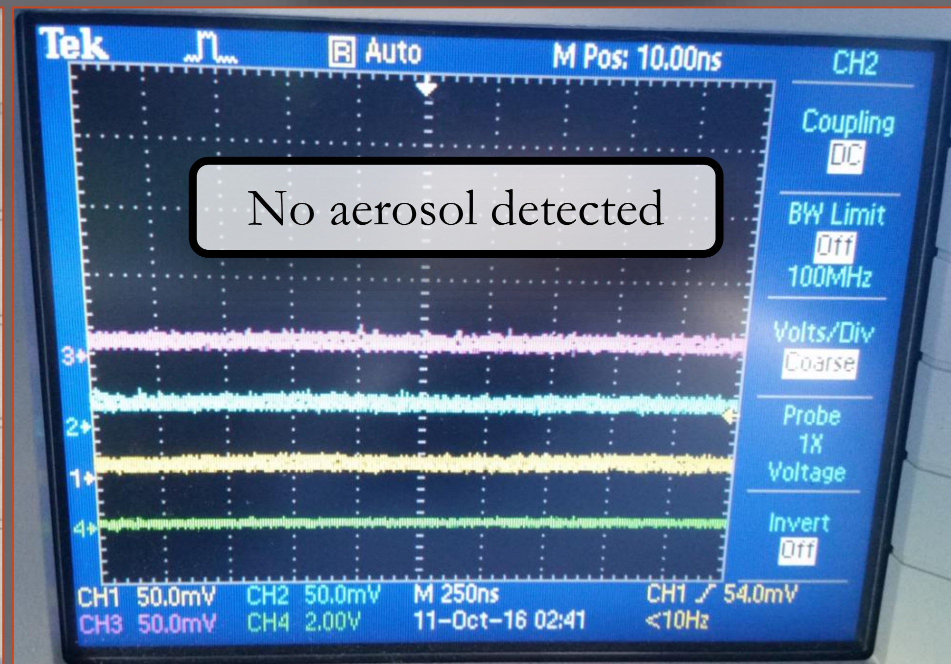
Upstream Baghouse Flue Gas Treatment

PDI measurements on SSTU outlet:

December 2015

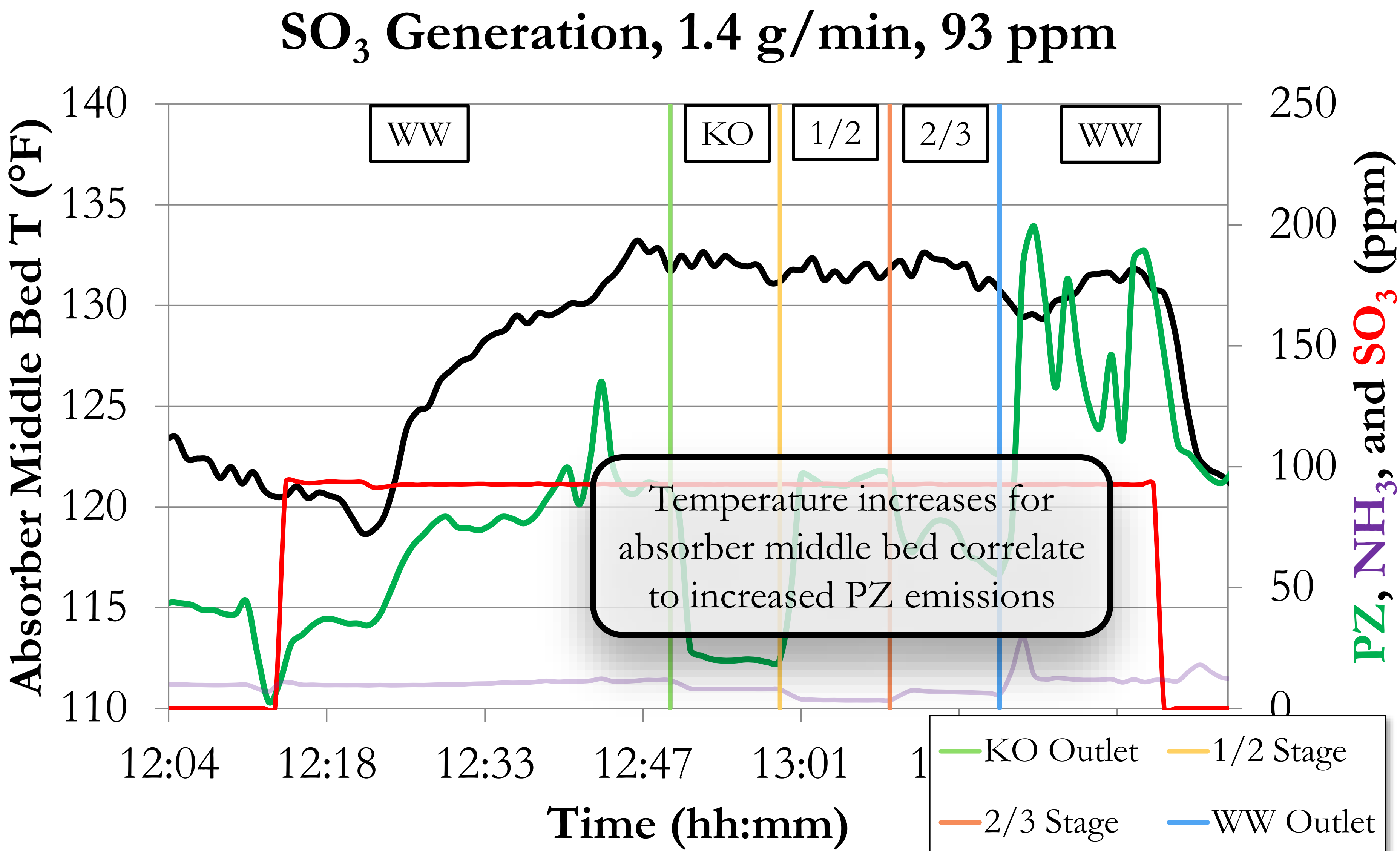


October 2016

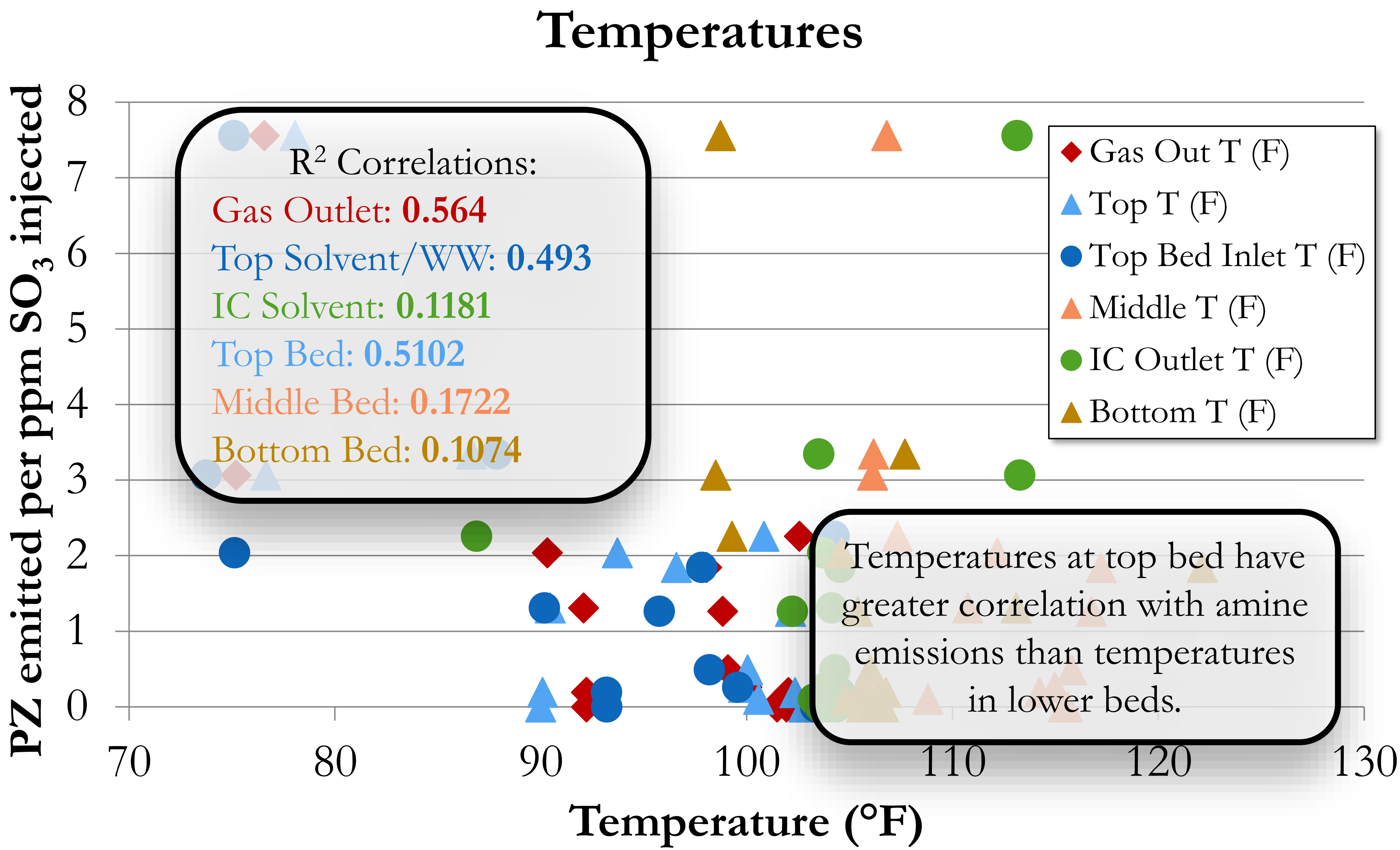


Lack of aerosol confirmed with oscilloscope

Absorber T Effect on PZ Emissions



Aerosol Emission Correlations



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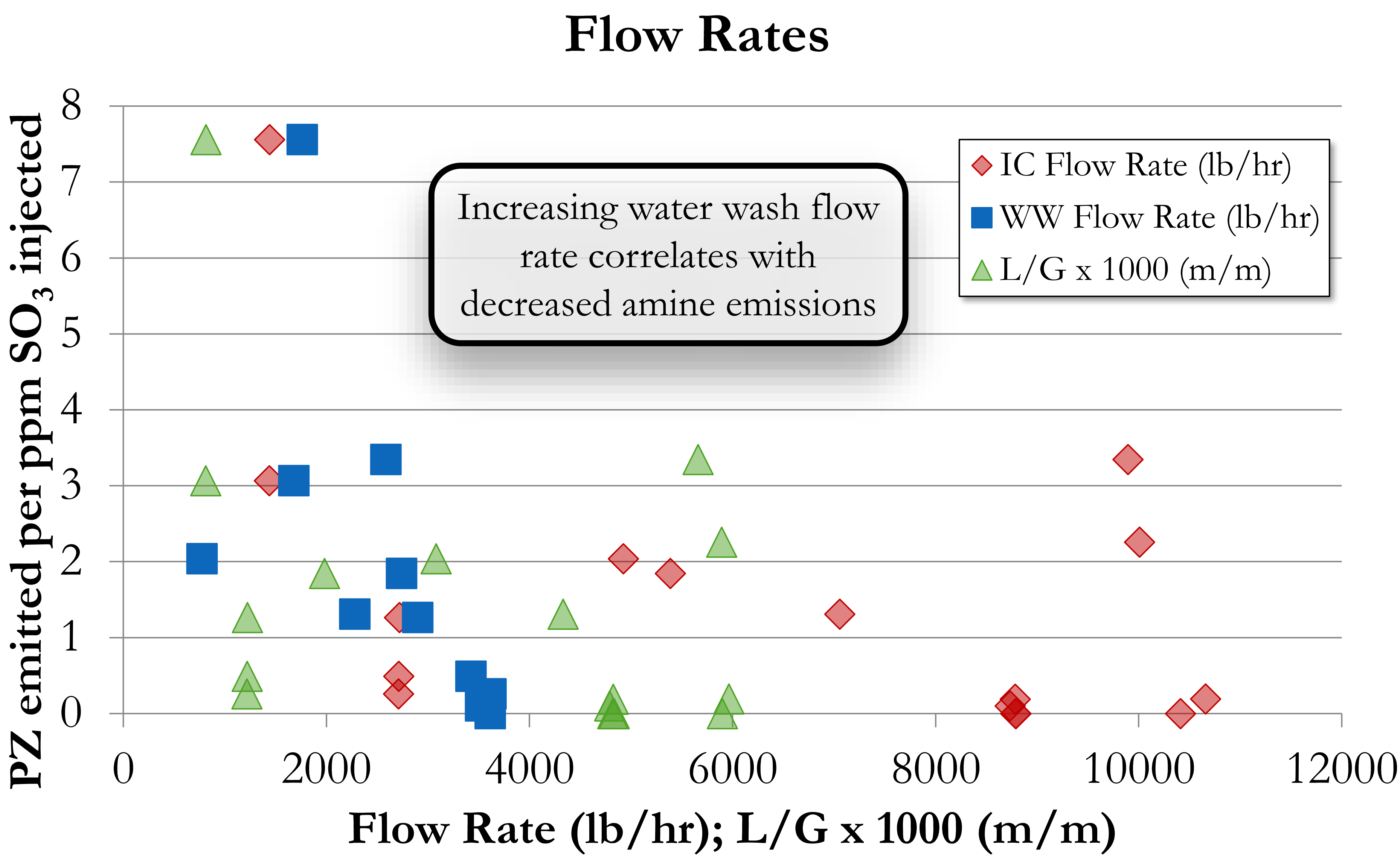

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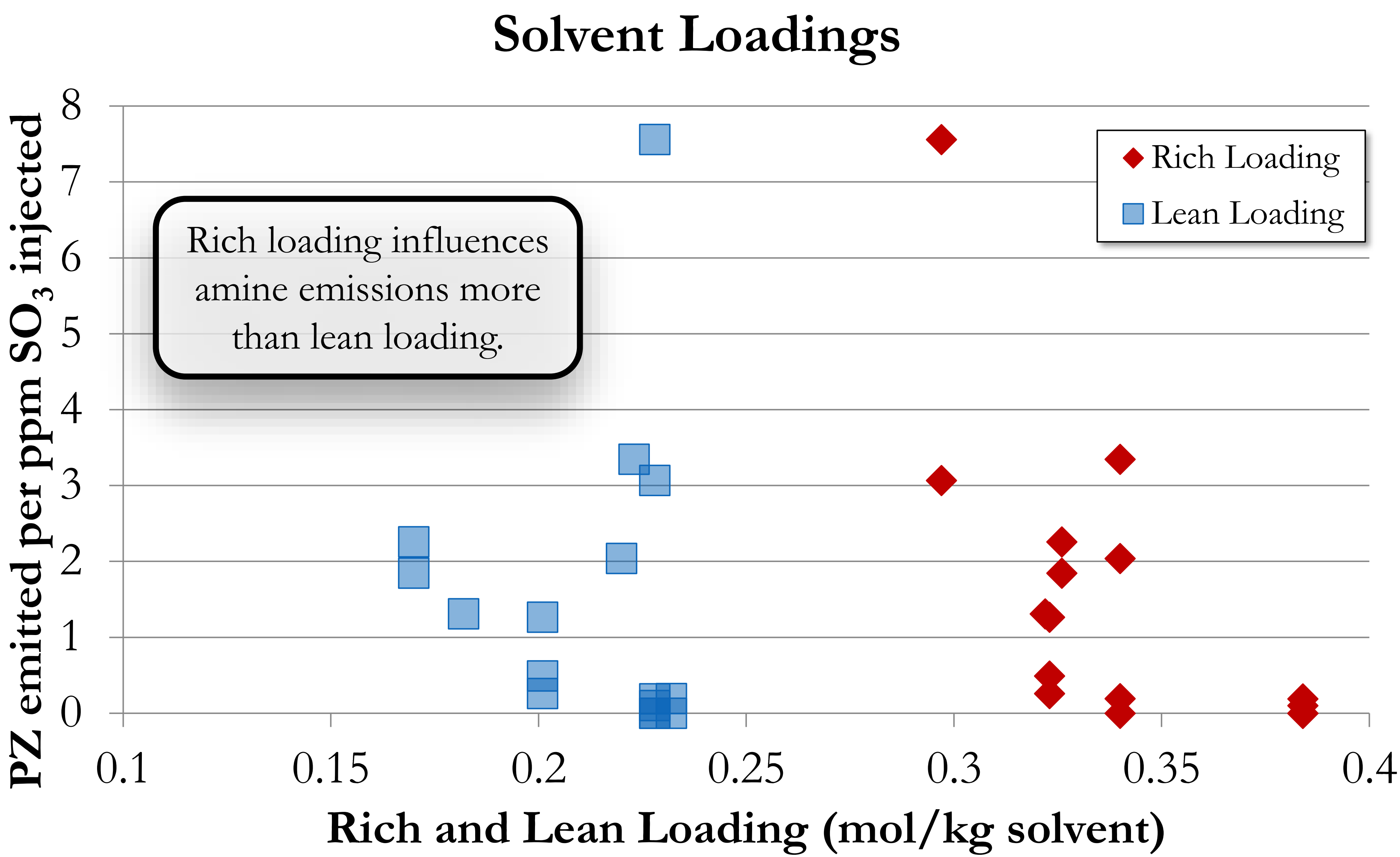
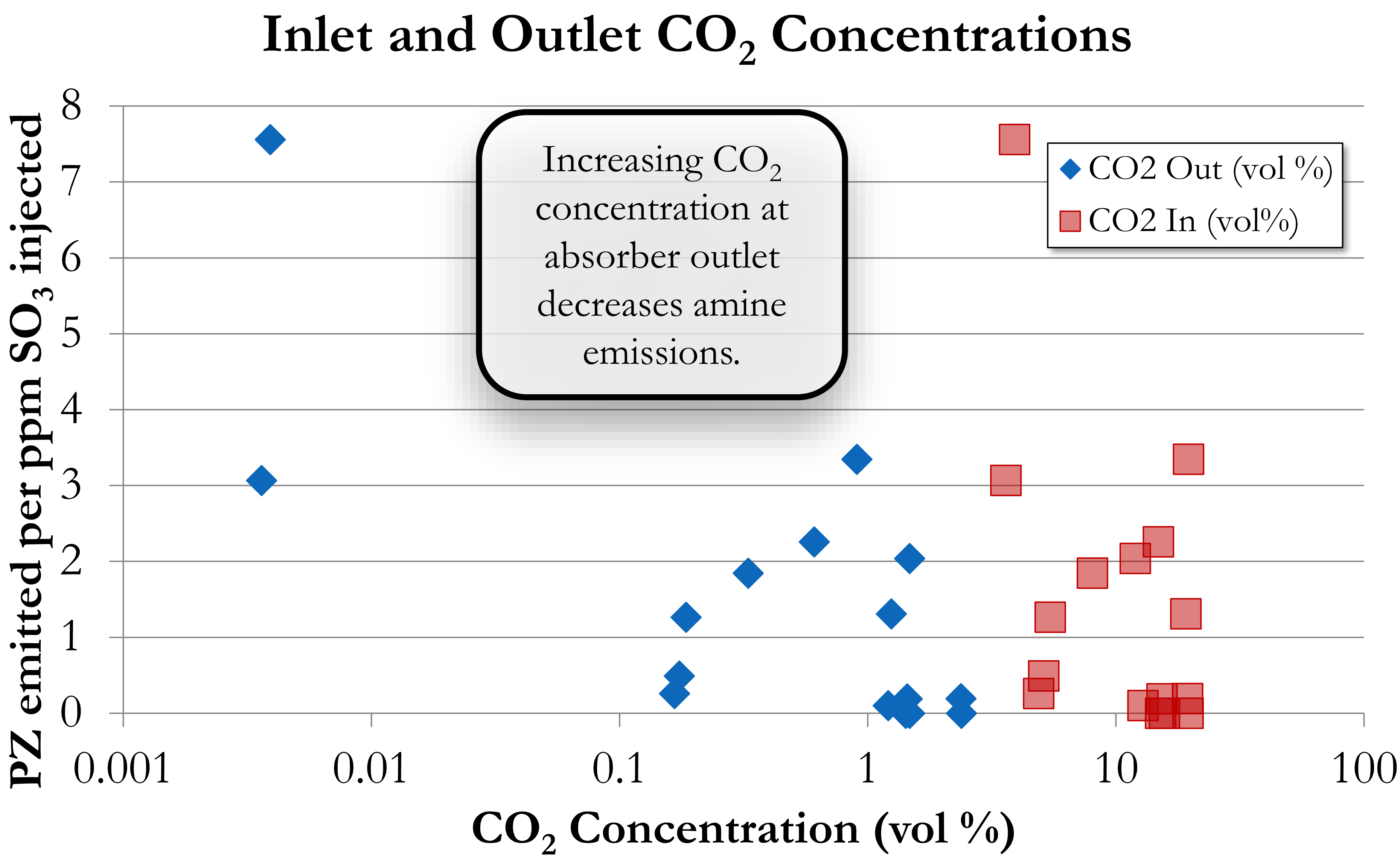


Aerosol Emission Correlations

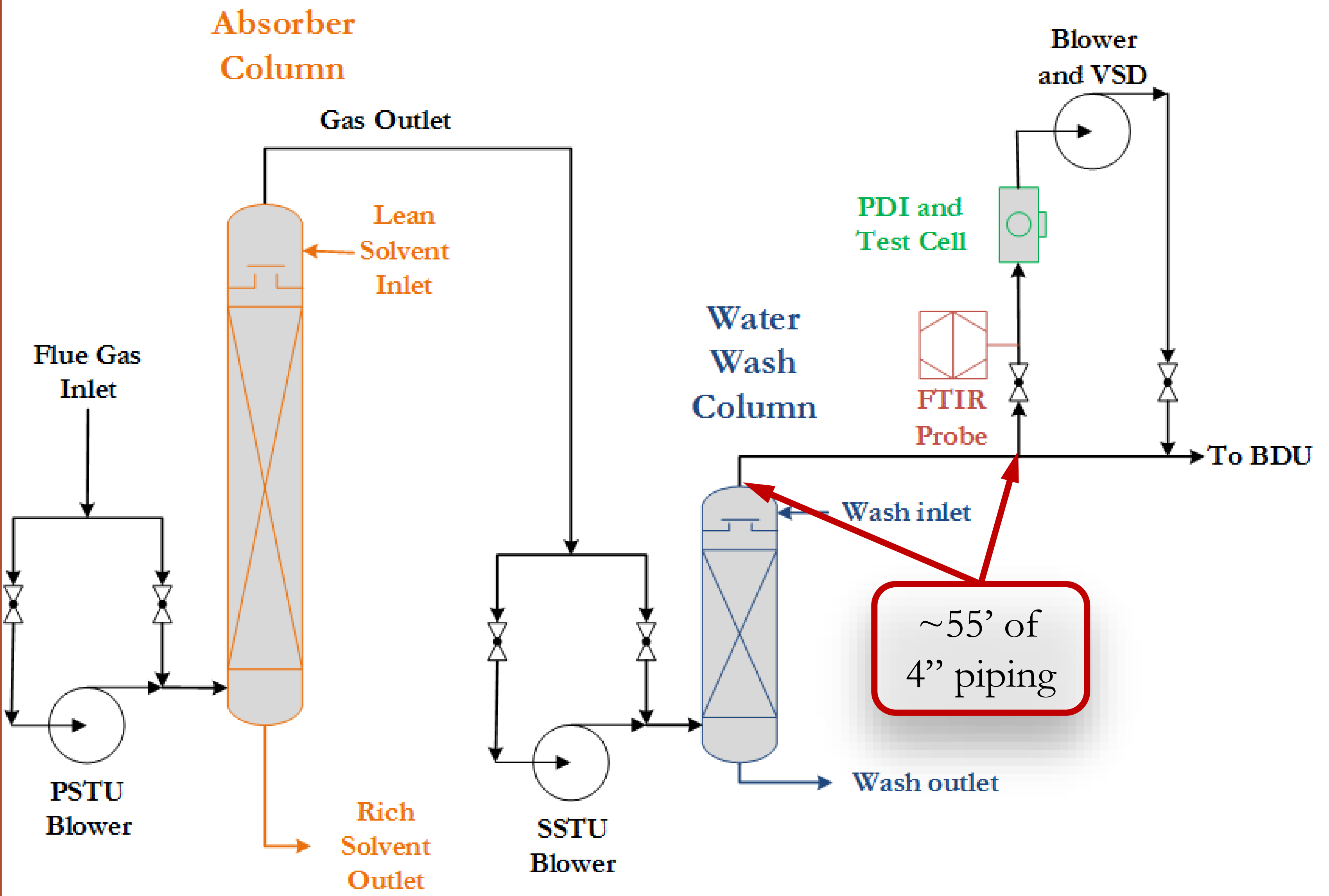
Solvent Loadings	R^2
Rich Loading	0.367
Lean Loading	0.005

- Rich loading has greater influence on amine emissions than lean loading

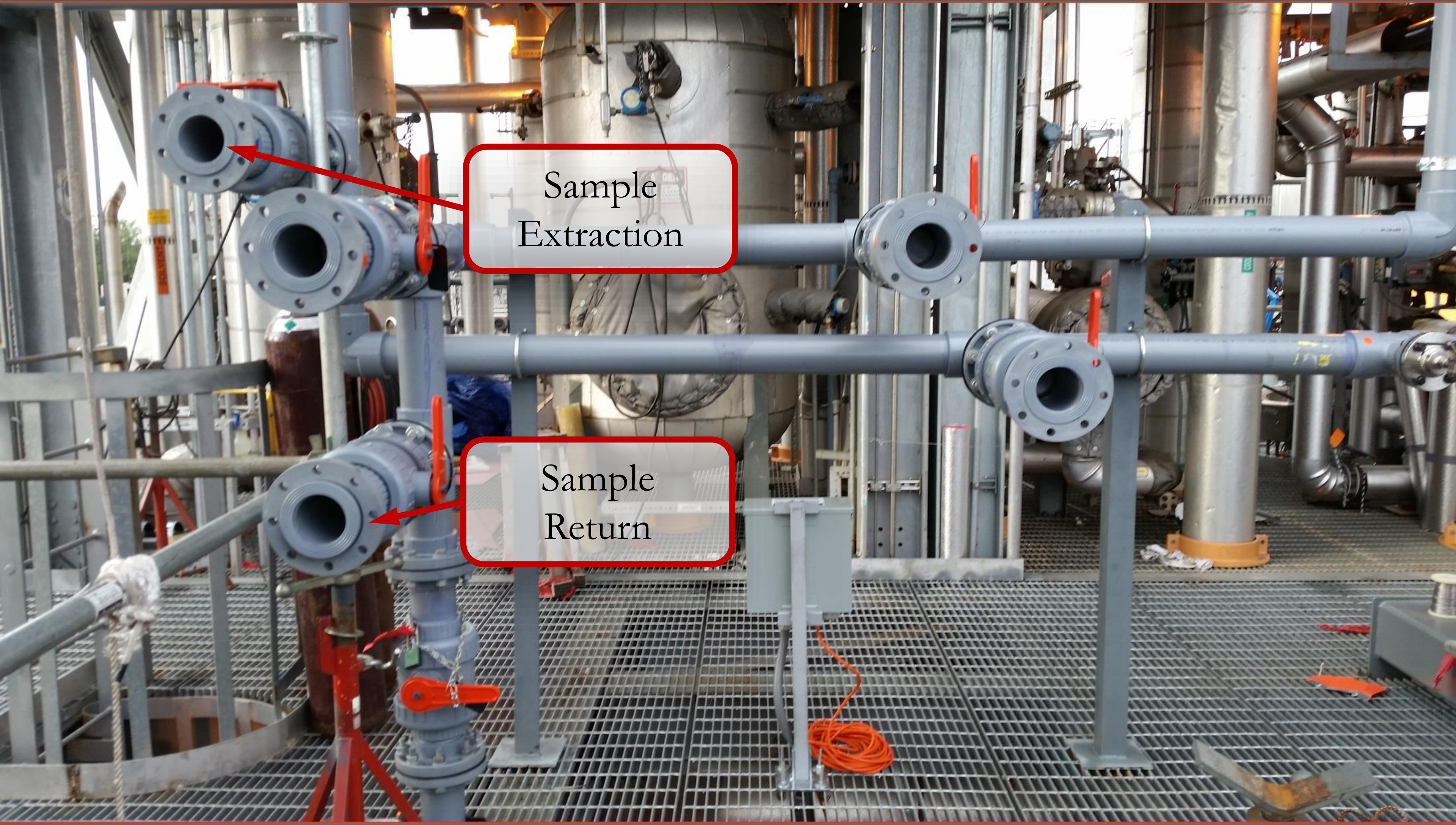
Aerosol Emission Correlations



NCCC SSTU


Absorber Column
Gas Outlet
Lean Solvent Inlet
Flue Gas Inlet
PSTU Blower
Rich Solvent Outlet
SSTU Blower
Water Wash Column
Wash inlet
Wash outlet
PDI and Test Cell
FTIR Probe
Blower and VSD
To BDU
~55' of 4" piping

FTIR and PDI Field Sampling



FTIR and PDI Field Sampling