PILOT PLANT TESTING OF PIPERAZINE WITH THE ADVANCED FLASH STRIPPER AT 3.5 TO 20% CO2

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C2P3 & UT PZ Pilot Plant Testing

2008

8 m PZ
Absorber
Mellapak 2X
Simple Stripper

2010

8 m PZ
AbsIntercooling
RSP 250-hybrid
Simple Stripper
120 °C

2010/2011

8 m PZ
AbsIntercooling
RSP 250-hybrid
2-Stage Flash
150 °C, 12 bar

2011

8 m PZ
AbsIntercooling
GTC-350Z, 70°
2-Stage Flash w/
Warm Rich Bypass
150 °C, 14 bar

2013

4 m PZ
AbsIntercooling
RSP-250
1-Stage Flash w/
Cold Rich Bypass
140 °C, 4.4 bar
Aerosols, G2 PDI

2015

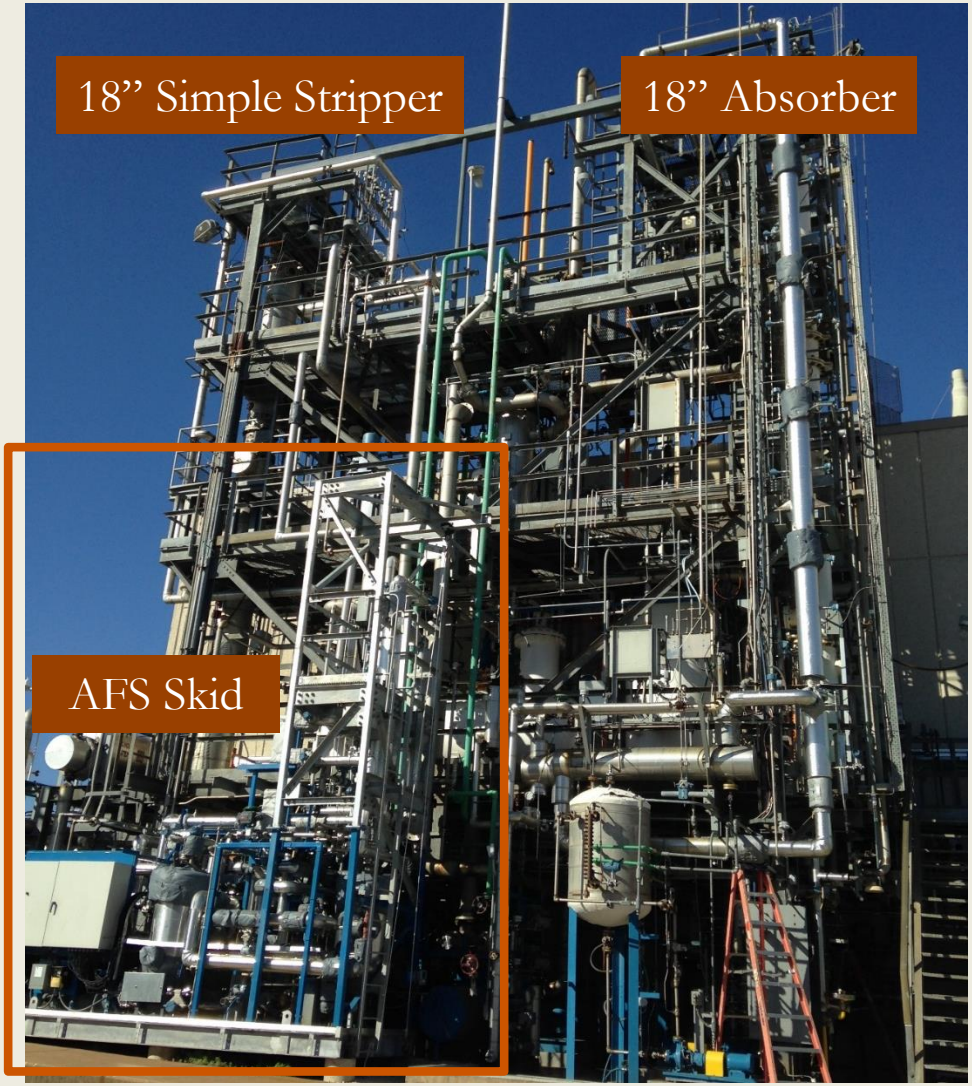
5 & 8 m PZ
AbsIntercooling
RSP-250
6" Adv Flash Stripper
Cold/Warm Rich
Bypass, 150 °C, 8 bar
Aerosols, G3 PDI

2017

5 m PZ
3.5-20% CO_2
AbsIntercooling
RSP-250 (30 ft)
Water Wash
10" Adv Flash Stripper
Cold/Warm Rich
Bypass, 150 °C, 8 bar
Aerosols, G3 PDI

Current Pilot Facilities & Equipment

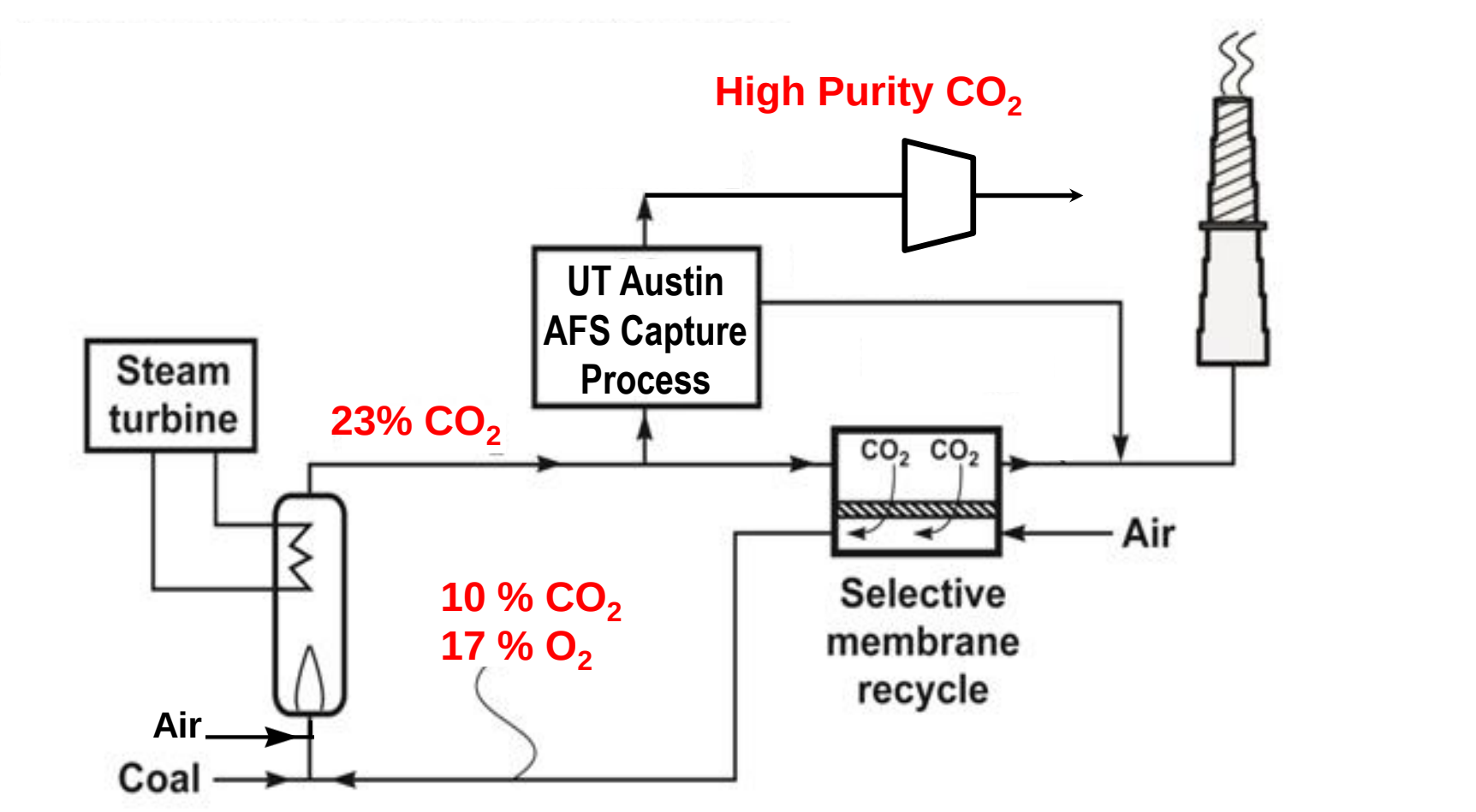
- SRP - 0.1 MW, 16.8-inch ID
- 200-450 lb CO_2/hr removal
- Synthetic Flue Gas: Air/CO_2
  - Enthalpy, 1-2 % H_2O, 30-40 °C
  - 3-20% inlet CO_2
  - Air max. oxidative degradation
- 30 feet (6.1 m) absorber packing
- Absorber intercooling
- 0.1-0.2 MW 10” AFS skid w/cold and warm rich bypass



April/May 2017 Pilot Plant Campaign

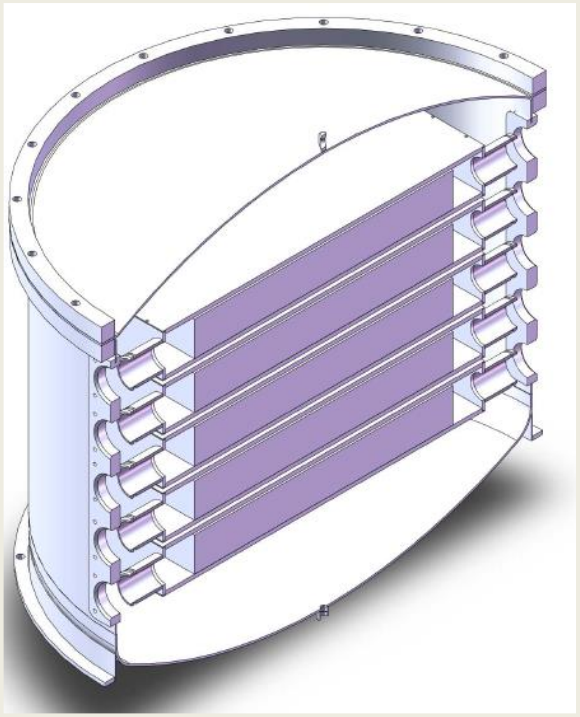
- 20% CO_2 – Parallel hybrid membrane-amine process (MTR-DOE Project)
- 12% CO_2 – Coal benchmark
- 3.5% CO_2 – Natural gas conditions
- 4 weeks, 24 hr day, weekend shutdown
- 29 runs
- 5 m PZ
- Absorber w/intercooling
  - 30 ft (3 x 10 ft beds)
  - 20 ft (2 x 10 ft bed) + 10 ft water wash
- 10" Advanced flash stripper

DOE-MTR Hybrid Membrane Project



- 90% Capture Rate for the Capture System
- Absorption process removes 95%+ CO_2 from a split flue gas stream

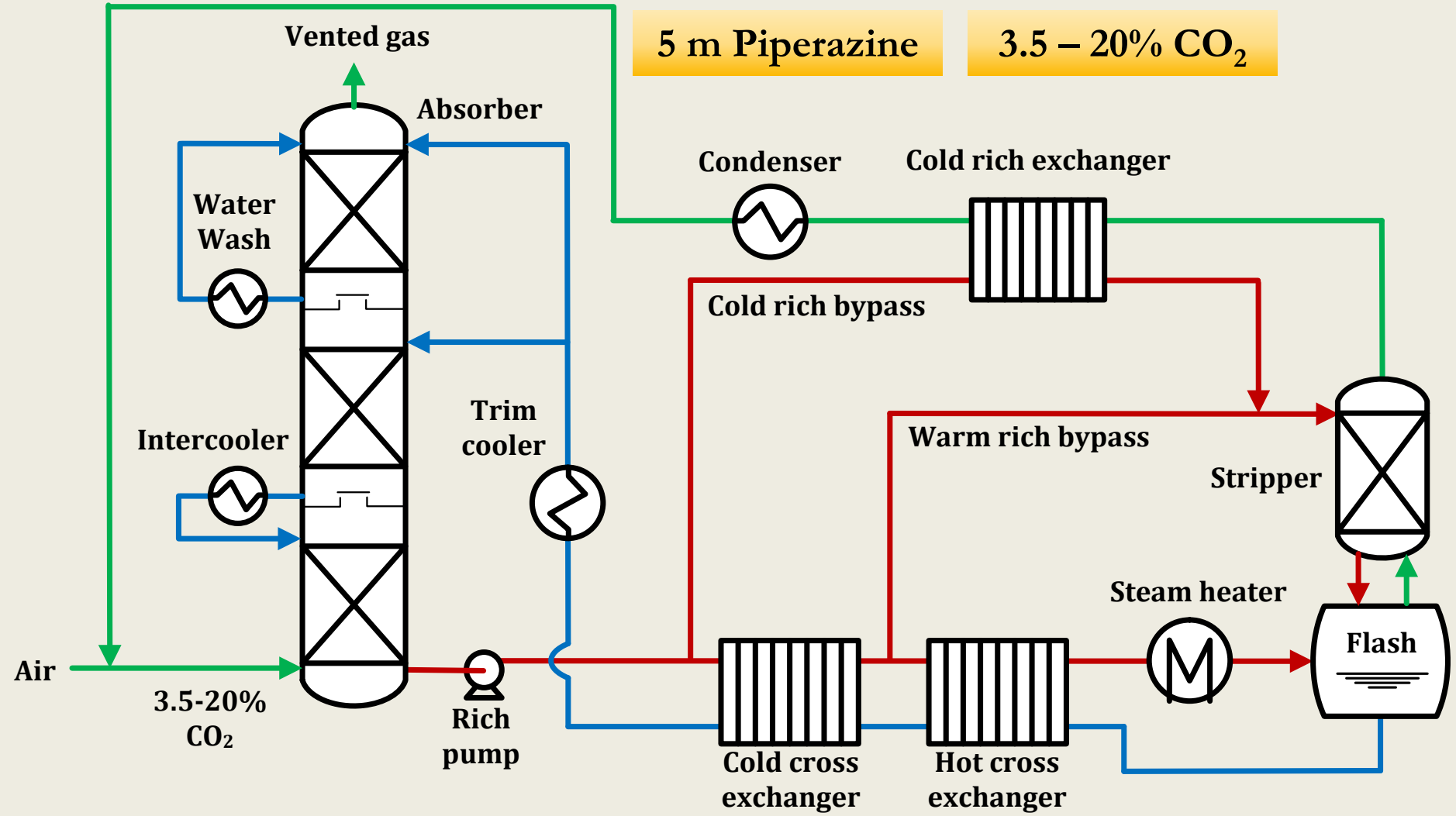
MTR Low Pressure Drop Plate-and-Frame Membrane Contactor



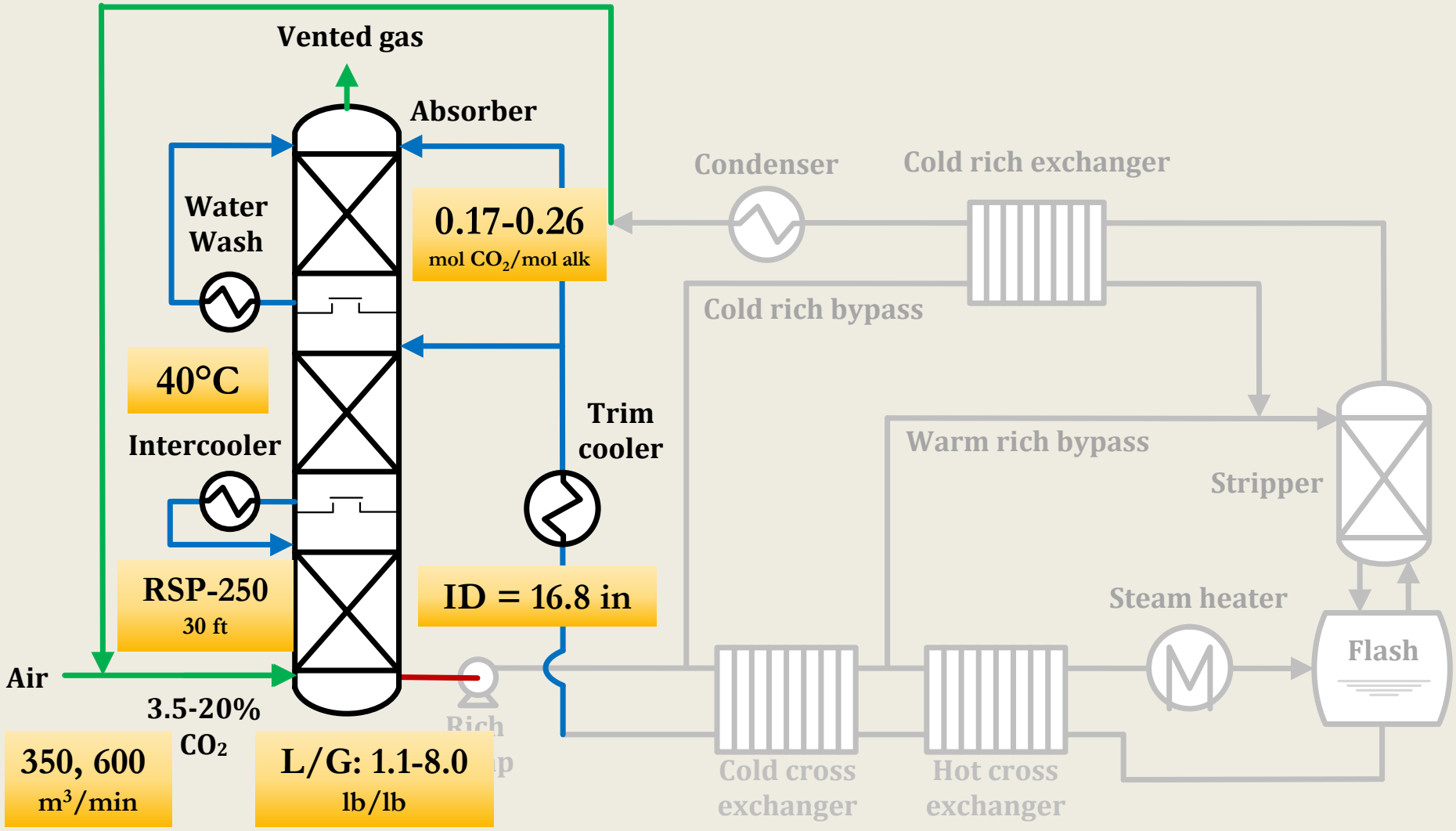
500 m^2 R&D Skid:
5 elements bundled in one vessel.

Polaris plate-and-frame sweep modules
(designed in DE-NT007553)

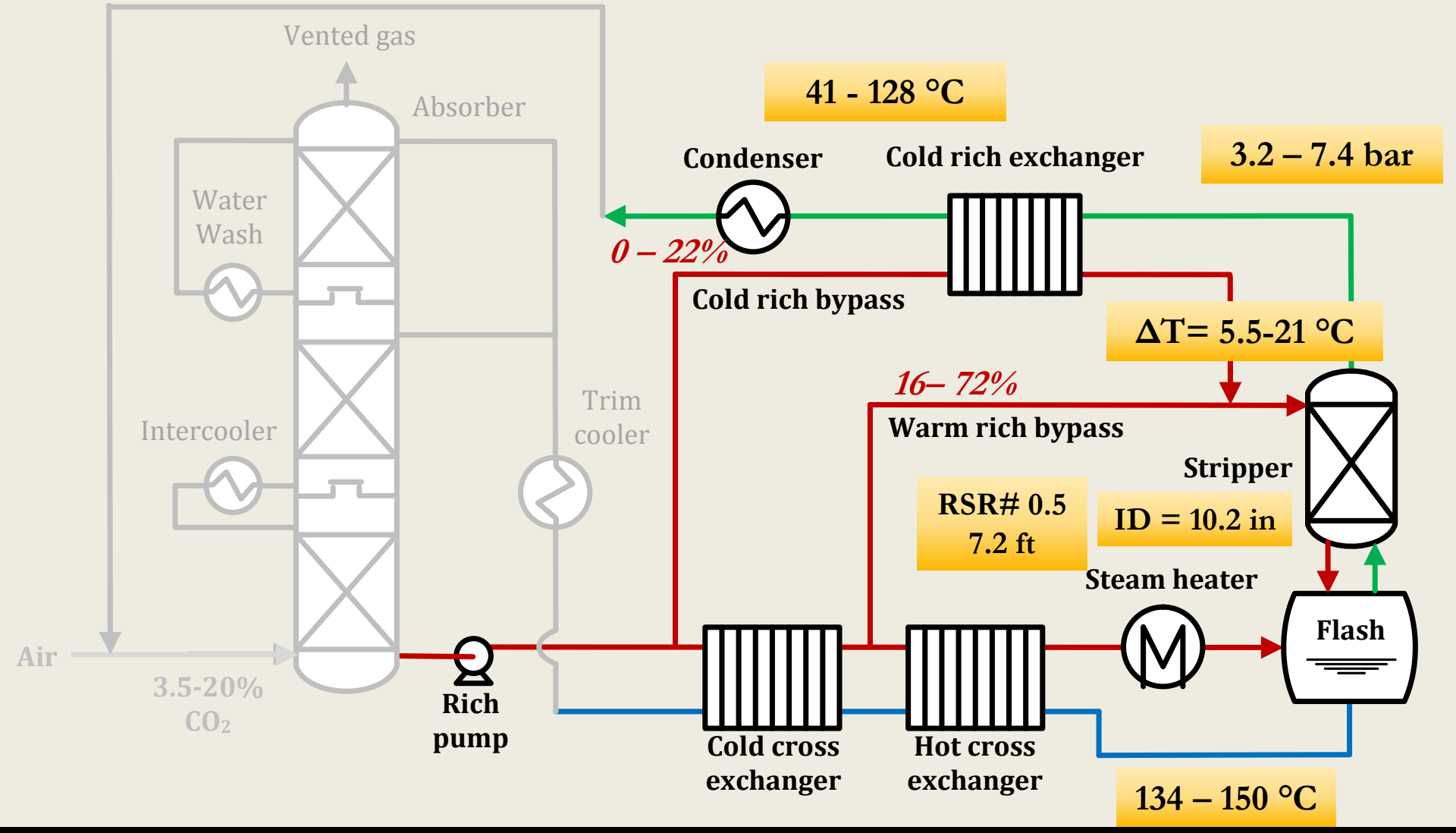
2017 AFS Campaign Configuration



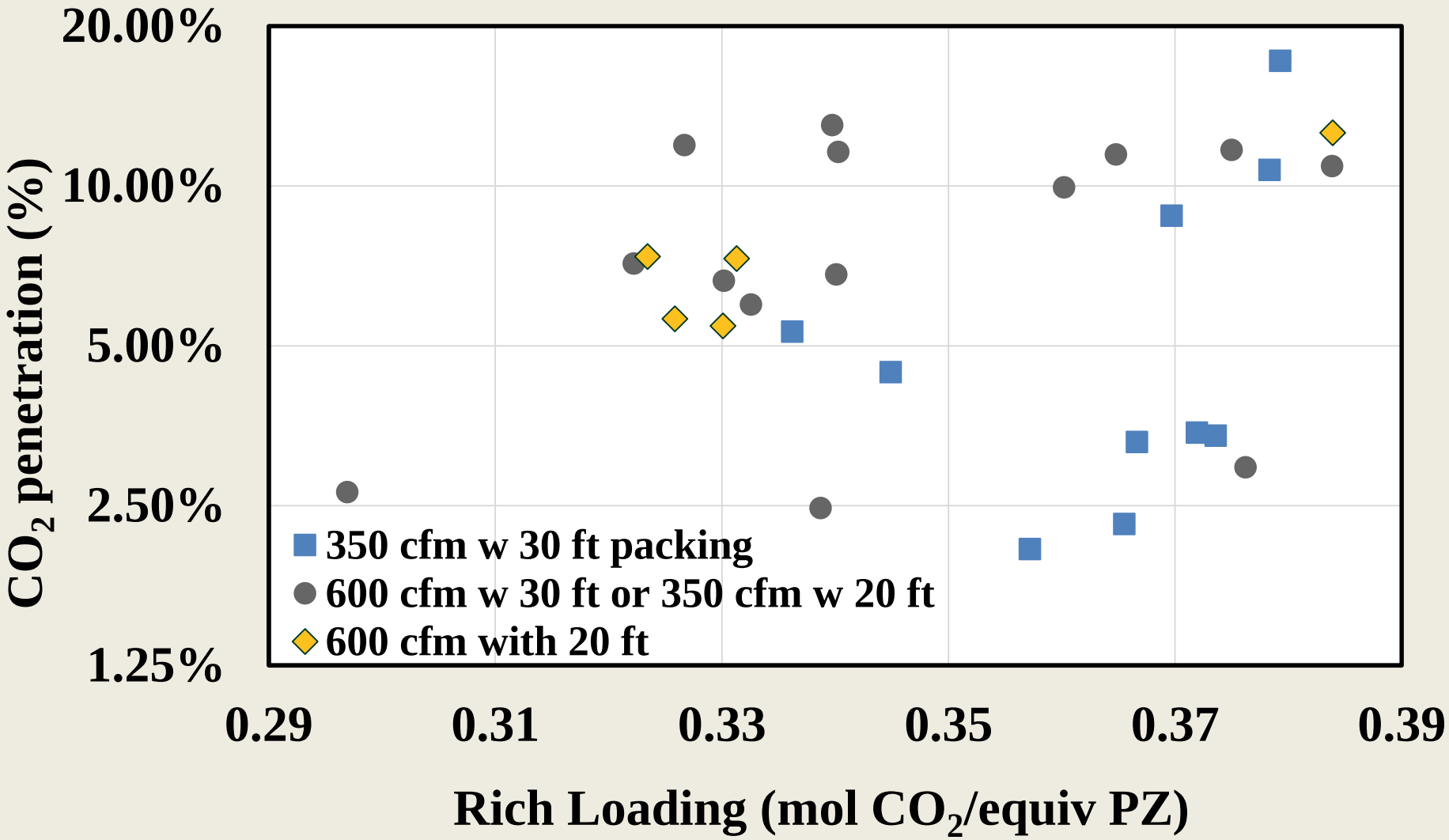
Absorber Conditions



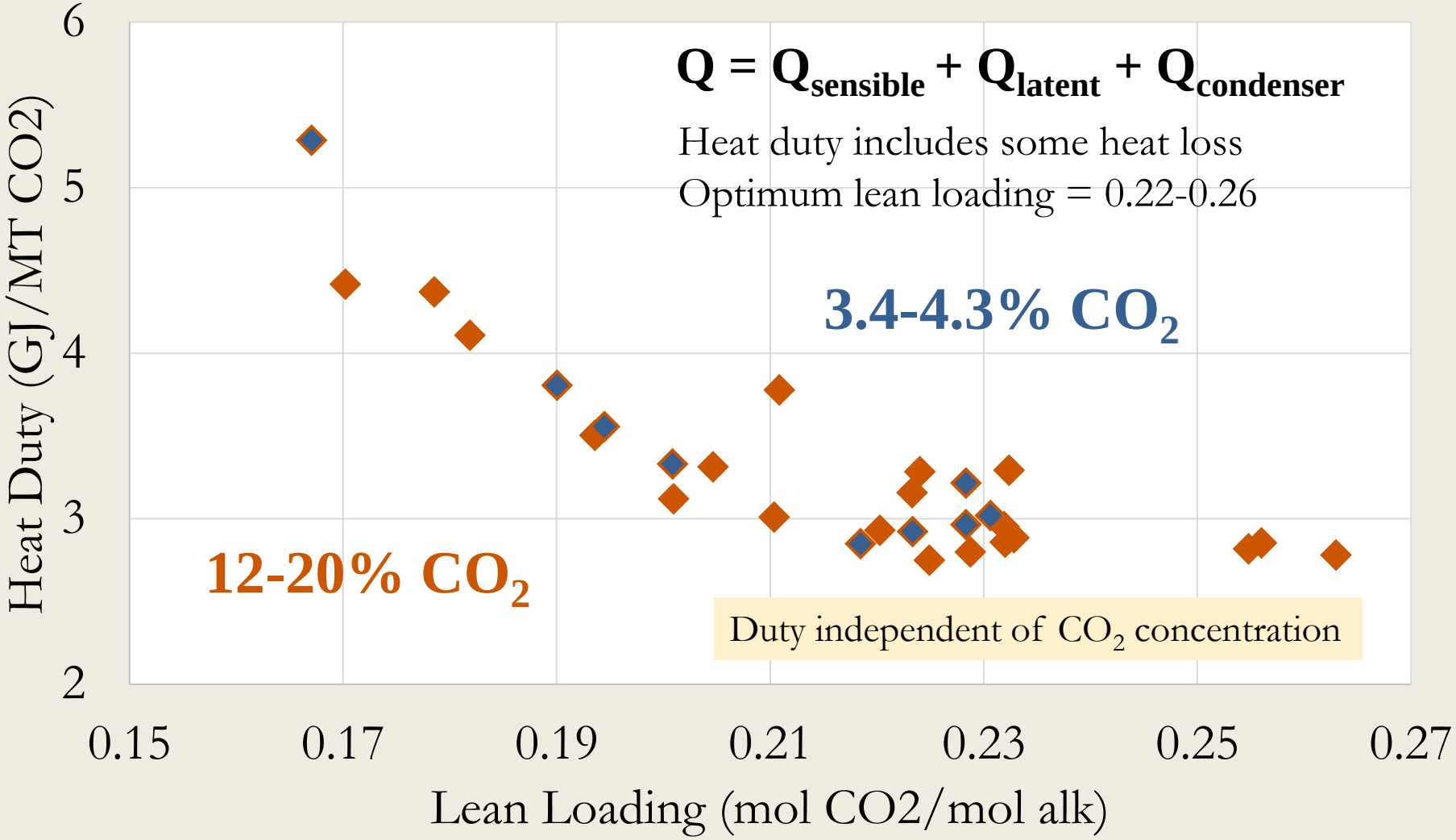
Stripper Conditions



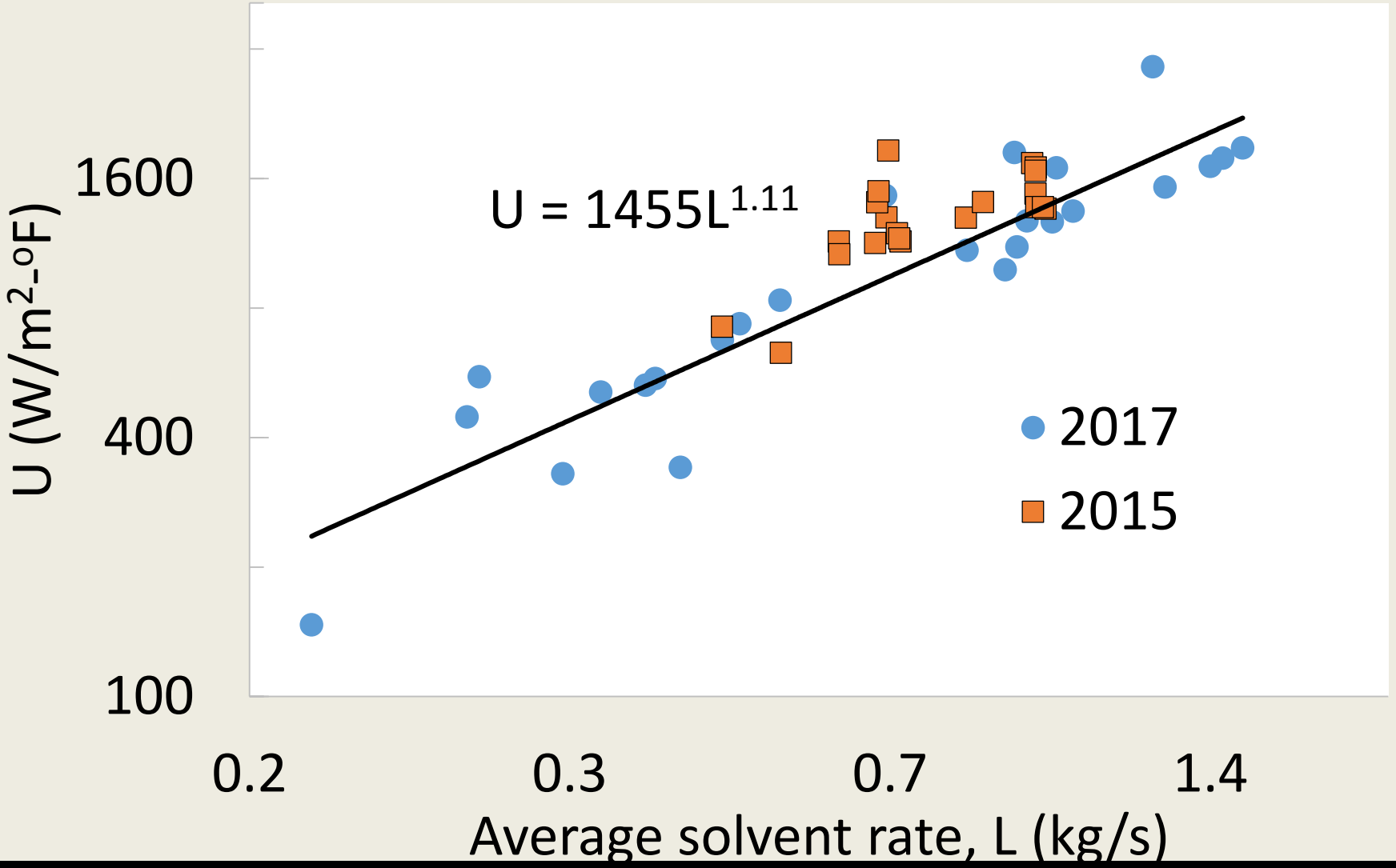
Absorber Performance



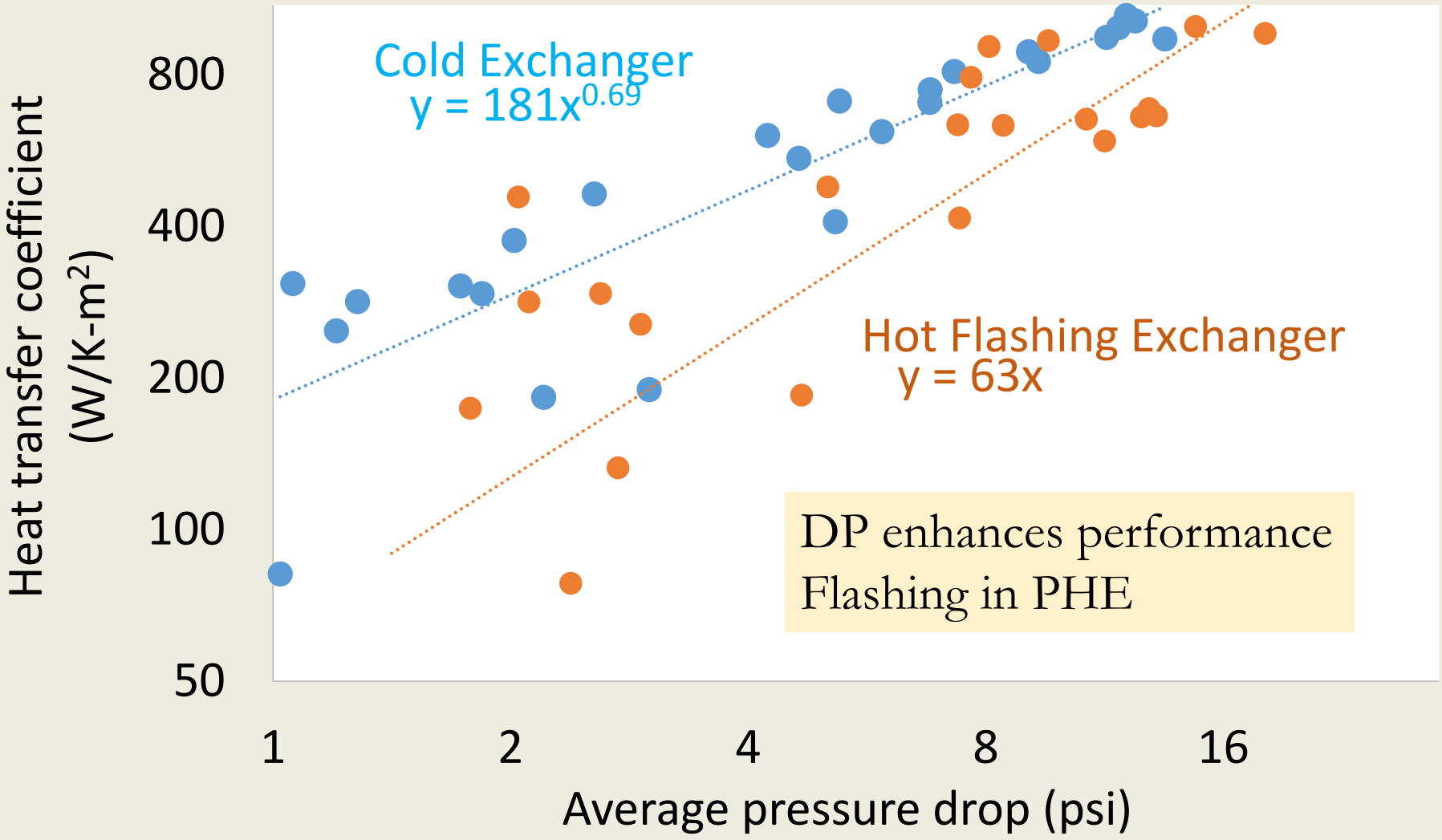
AFS Heat Duty Results



Cold Cross Exchanger Performance



Cross-Exchanger Performance



PZ Management Results

- Precipitation minimized by 5 m PZ
  - Instr air loss + chilled water to IC = precipitation
  - Melted at 80 °C with heat gun
- Foaming
  - Moderate unexpected absorber DP at high gas rate (600 cfm)
  - Reduced to normal by addition of antifoam
- Oxidation is acceptable
  - NH_3 emissions of 3 to 10 ppm, could still be reduced
- Aerosol requires high SO_3 (Beaudry/Akinpelumi)
  - PZ emissions doubled with 10 -100 ppm SO_3
- Corrosion of CS could be acceptable for stripper shell (Fischer)
  - 175 (SS), 325 (CS) mm/yr in hot lean PZ

2017 PP Conclusions

- Absorber & stripper performed well with 20% CO_2
- Absorber predicted acceptably by "Independence" Aspen process model (Zhang)
  - Absorber model most accurate for 4% and 12% CO_2
  - Liquid distribution poor at high L/G
- Energy requirement independent of inlet CO_2
  - Heat loss needs more analysis
- Exchangers provide 4-8 °F pinch with 5 to 10% cold rich bypass
- Hot flashing P&F exchanger provides reliable heat transfer

Acknowledgements

- Members of CO_2 Capture Pilot Plant Project/PSTC
- URS/DOE Award DE-FE0005654
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- Raschig-Jaeger Technologies
- Emerson Process Management
- Texas Carbon Management Program