Bench Scale Development of a Hybrid Membrane-Absorption CO_2 Capture Process

DE-FE0013118

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NETL CO_2 Capture Technology Meeting
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Project Overview

- **Award name:** Bench-Scale Development of a Hybrid Membrane-Absorption CO_2 Capture Process (DE-FE0013118)
- **Project period:** 10/1/13 to 9/30/17
- **Funding:** $3.2 million DOE + $0.75 million cost share
- **DOE-NETL Project Manager:** Andy Aurelio
- **Participants:** MTR, University of Texas at Austin
- **Overall goal:** Evaluate a hybrid post-combustion CO_2 capture process for coal-fired power plants that combines membrane and amine absorption/stripping technology.
- **Project plan:** The key project work organized by budget period is as follows:
  - **BP1**: Develop process simulations and initial cost assessments for the hybrid process, determine preferred hybrid configuration. Fabricate membrane modules.
  - **BP2**: Prepare the SRP pilot plant for hybrid testing. Test each capture system separately under hybrid conditions.
  - **BP3**: Conduct a parametric tests on the integrated hybrid capture system at UT-Austin's SPR Pilot Plant. Use test data to refine simulations and conduct TEA.

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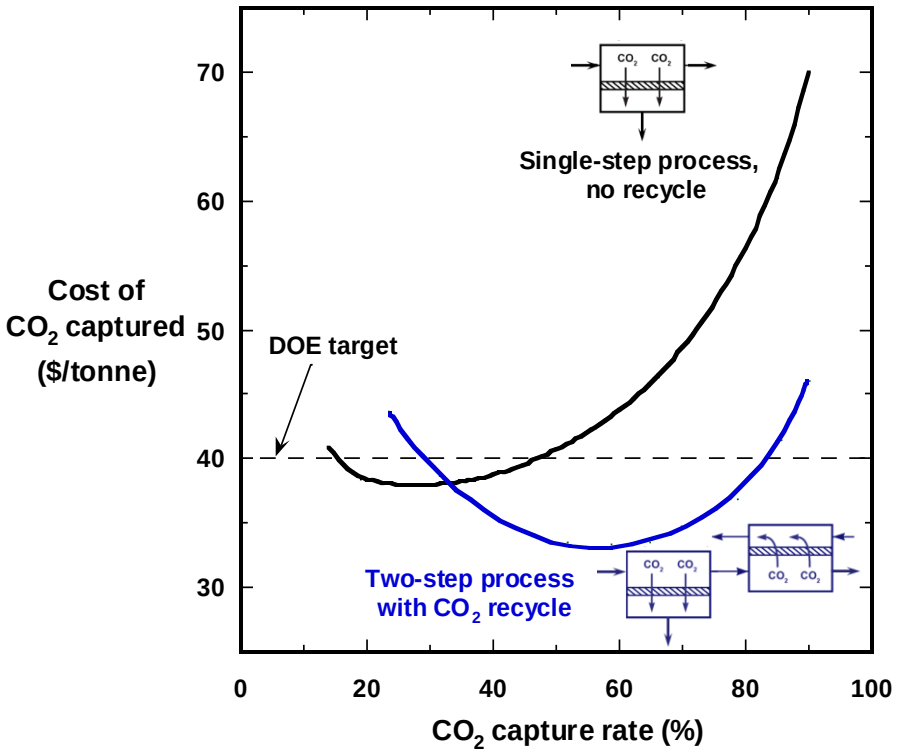
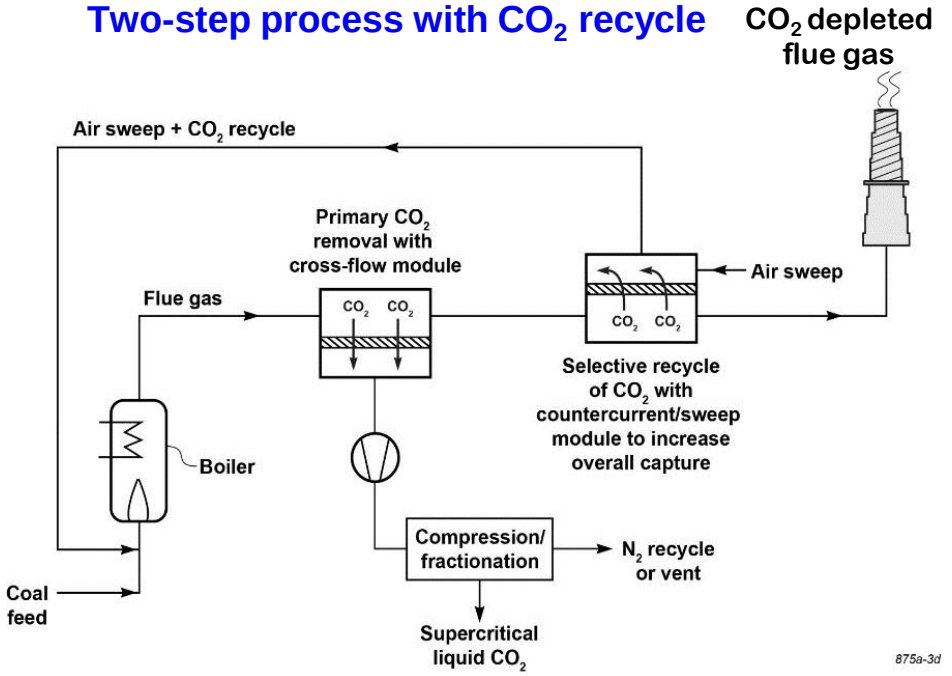
Motivation for the Hybrid Process





U.S. Patents 7,964,020 and 8,025,715

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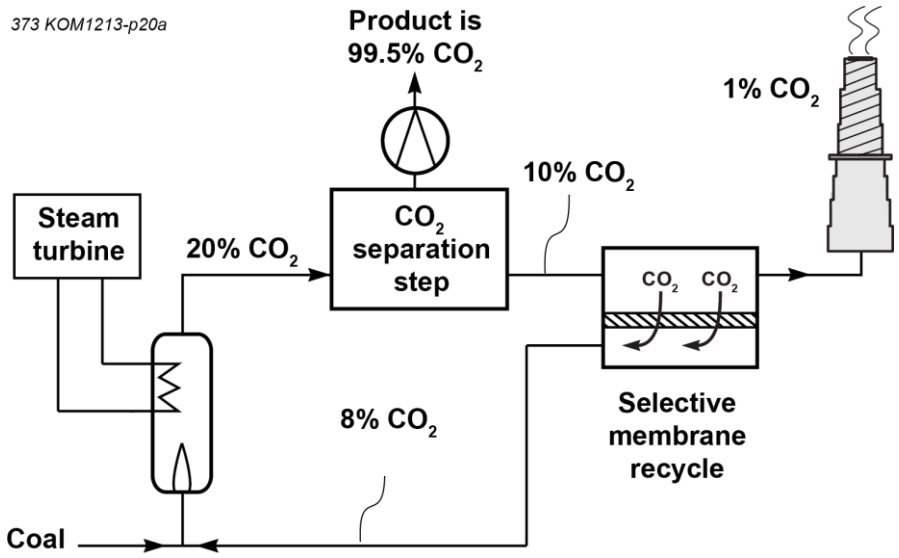
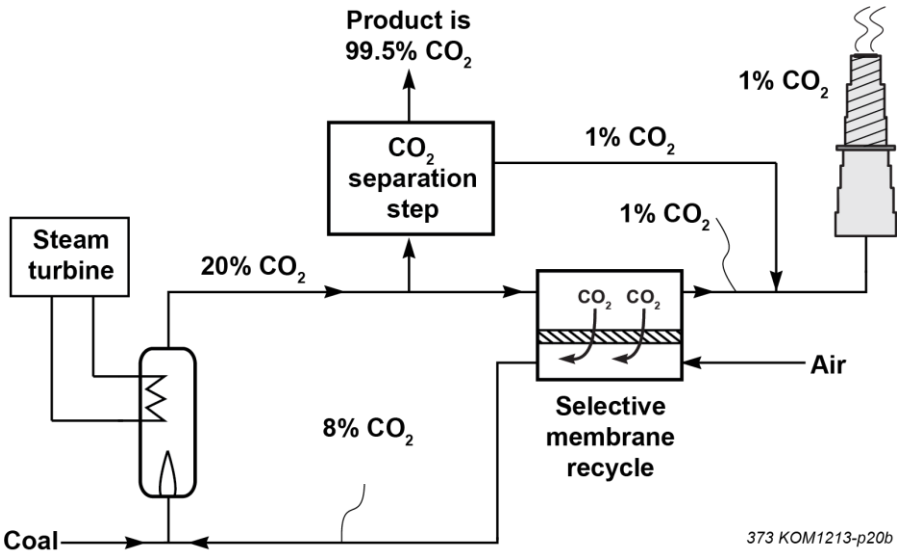
Two Hybrid Configurations

Hybrid-Series Arrangement



Hybrid-Parallel Arrangement



Depending on the arrangement, the selective recycle membrane can:

- Significantly increase the concentration of CO_2 in flue gas, and;
- Reduce the removal requirements for the capture unit (Series)
- Reduce the volume of gas sent to the capture unit (Parallel)

Benefits and Challenges of the Hybrid Capture Process

Benefits:

- Hybrid concept can be used with different capture technologies.
- Increases the concentration (driving force) of CO_2 in flue gas.
- Air sweep is a very efficient use of membranes.
- MTR's membrane contactor is modular and compact.

Challenges:

- Very permeable / low cost membranes required.
- Hybrid partner must be able to capitalize on high CO_2 concentrations.
- The sweep stream effects boiler performance (~0.8%) derating of boiler efficiency from CO_2 recycle in a retrofit application.
- Hybrid-parallel design requires greater removal rates (~95%) by the hybrid partner.

System Tests Scaled-Up Membrane Modules

Spiral wound sweep modules → **Tested Against** → **Polaris plate-and-frame sweep modules (designed in DE-NT007553)**

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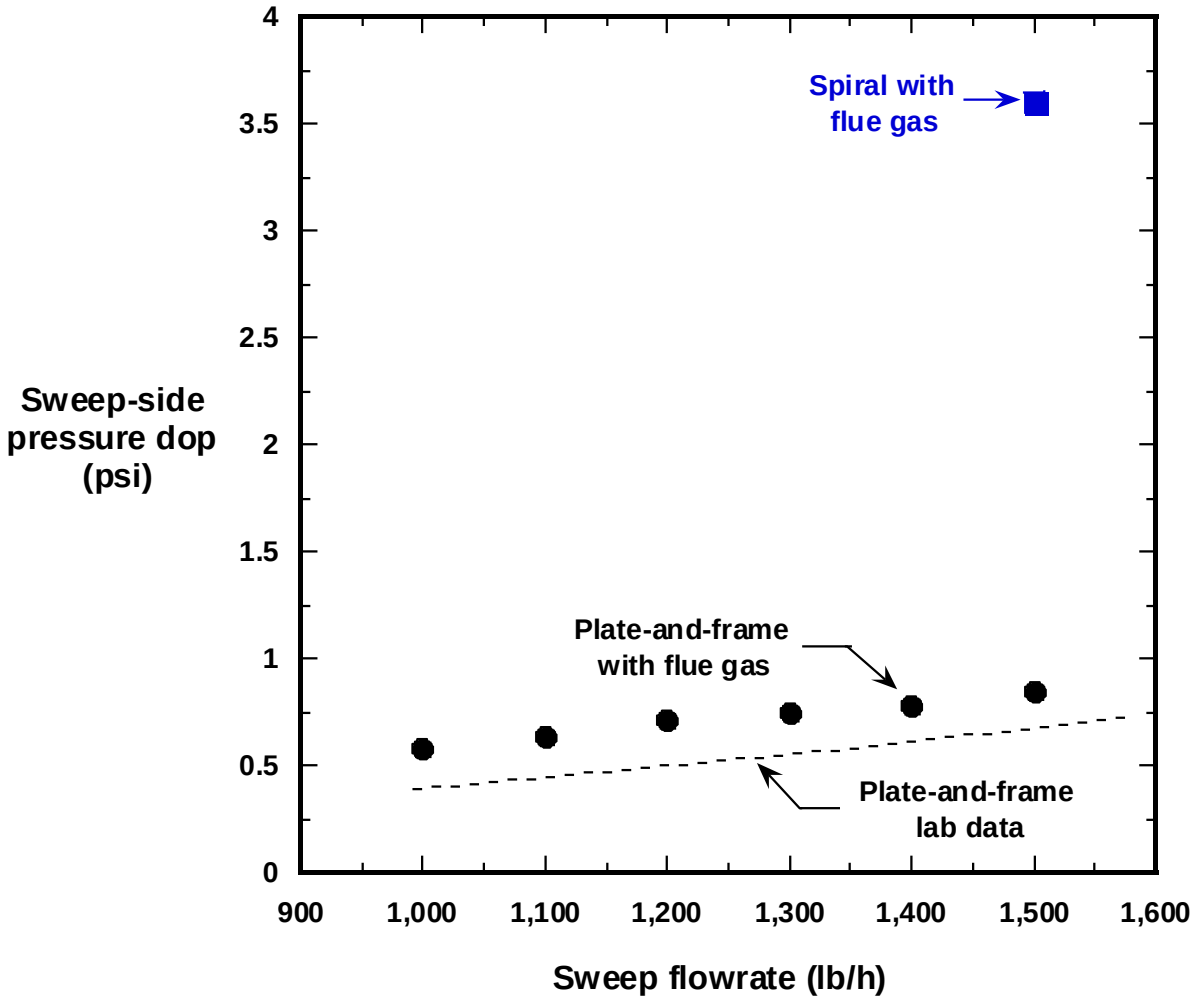
New Modules Demonstrate Improved Pressure Drop Performance



Field data from NCCC is consistent with lab results, and confirms much lower air sweep pressure drop in plate-and-frame modules

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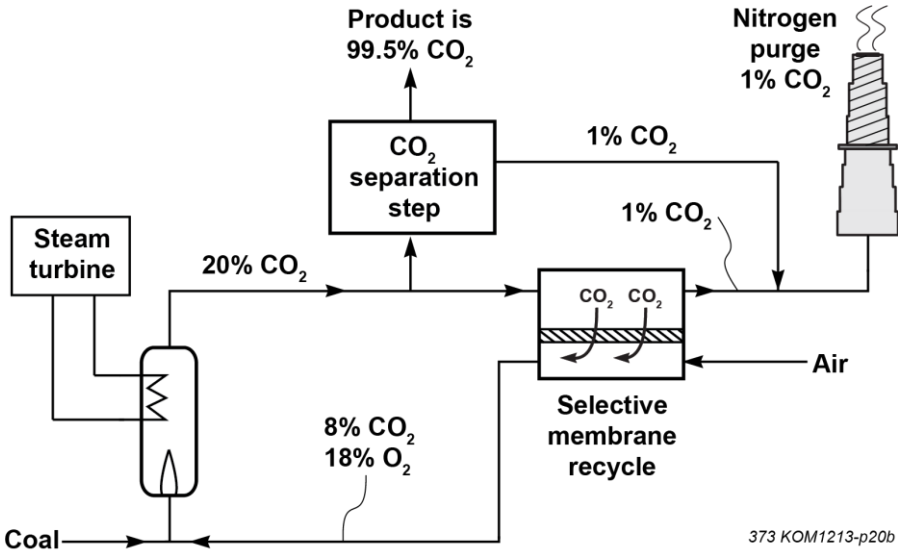
Sweep Module Testing in Hybrid-Parallel Conditions



	Feed Flue Gas	Residue	Sweep Air In	Sweep Air Out
Gas flow rate (ft^3/min)	6.9	4.7	12.2	14.6
Temp (°C)	19.4	20	20	19.7
Pressure (psia)	15.5	15.4	15.5	15.2
Pressure drop (psi)	--	0.1	--	0.3
Mol fraction CO_2 (%)	23.9	2.2	0.0	10.8
CO_2 Removal Rate	91%			

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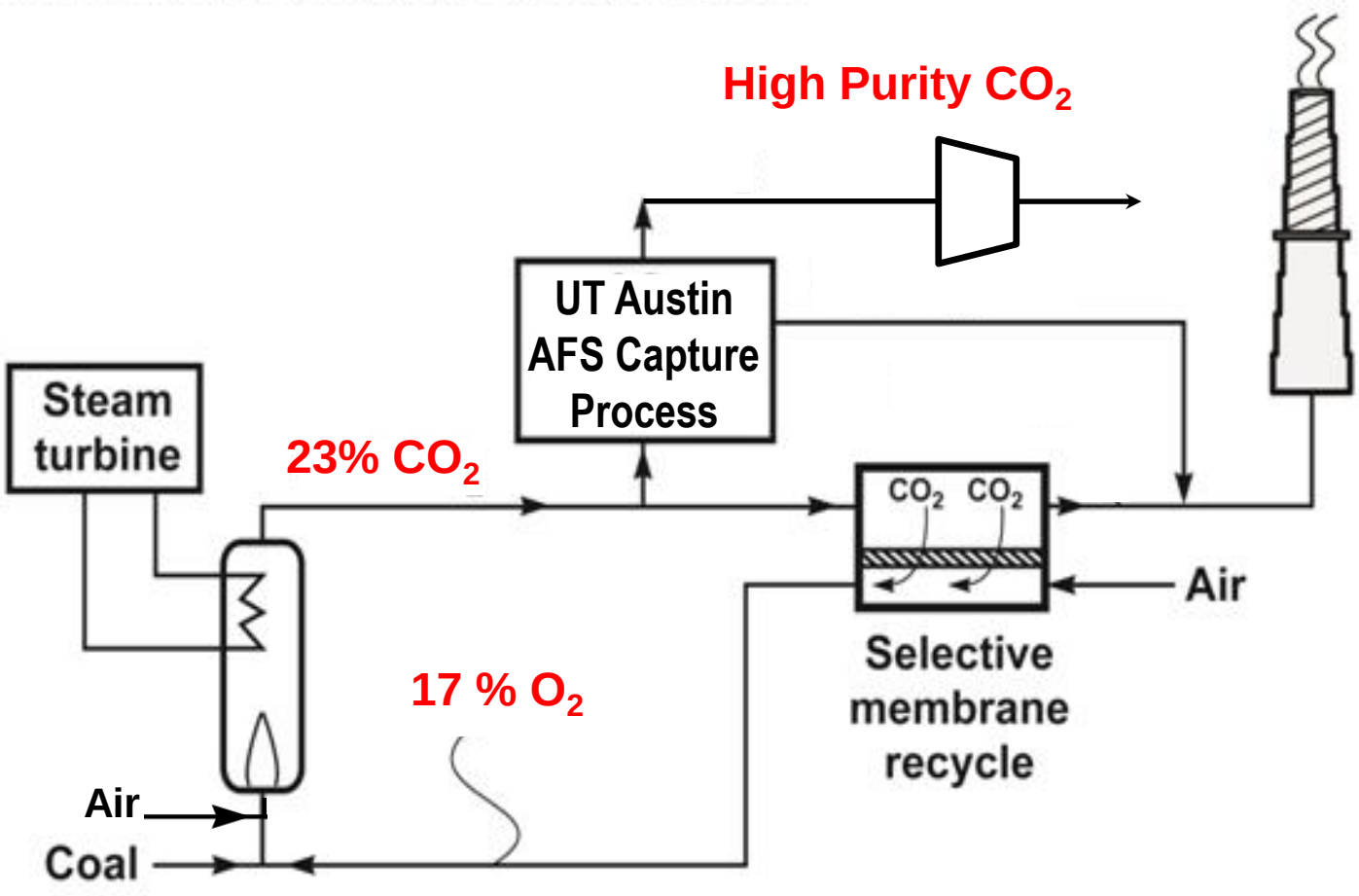
Hybrid Parallel System



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

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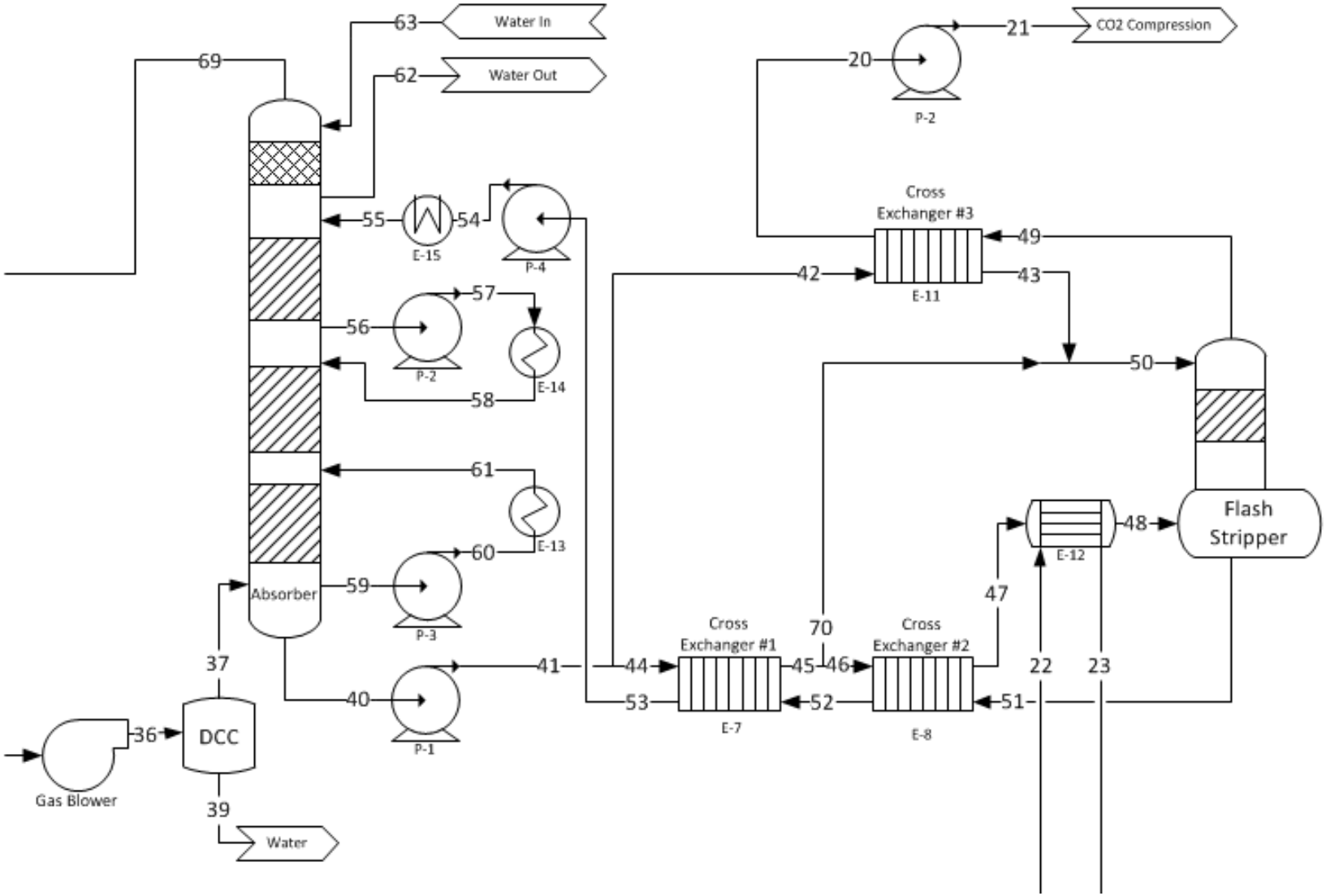
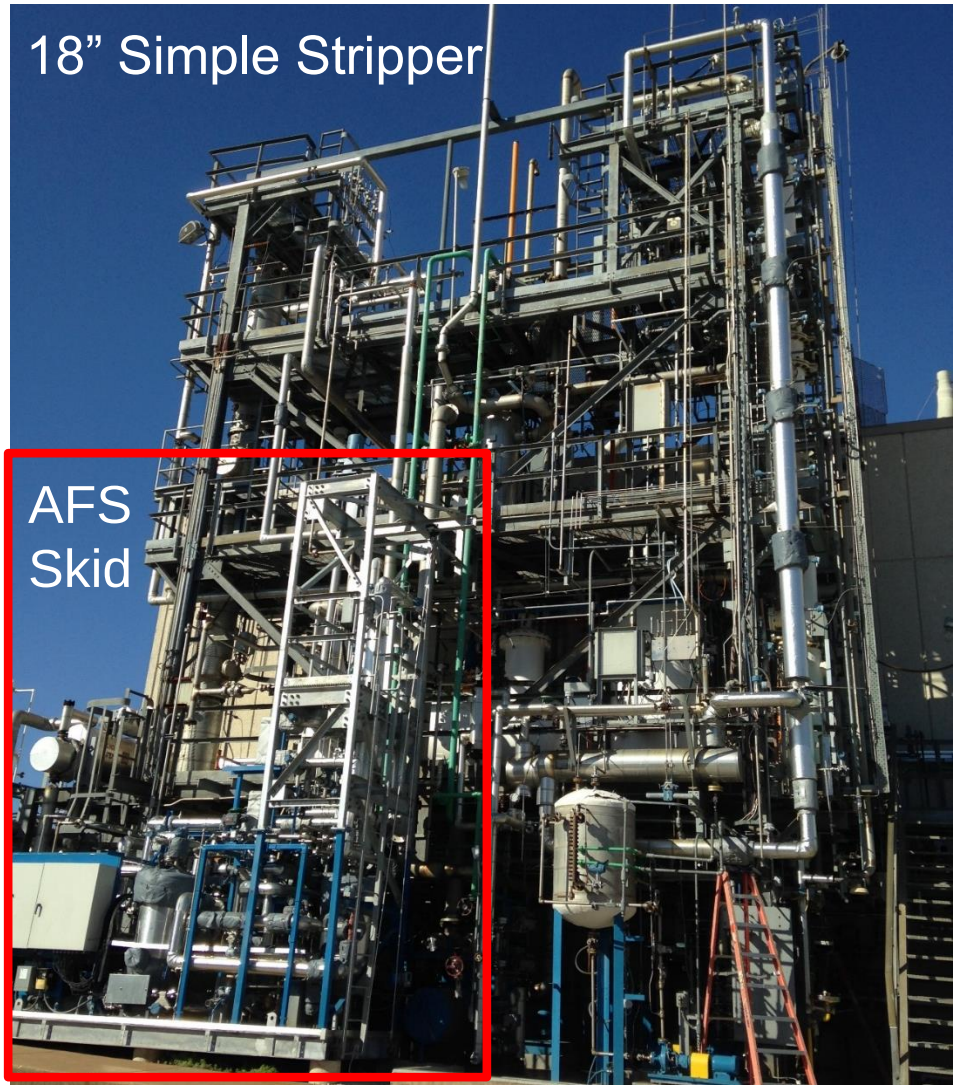
UT Austin's Advanced Flash Stripper (AFS) Capture Process, 5 m PZ



Current Pilot Plant Configuration

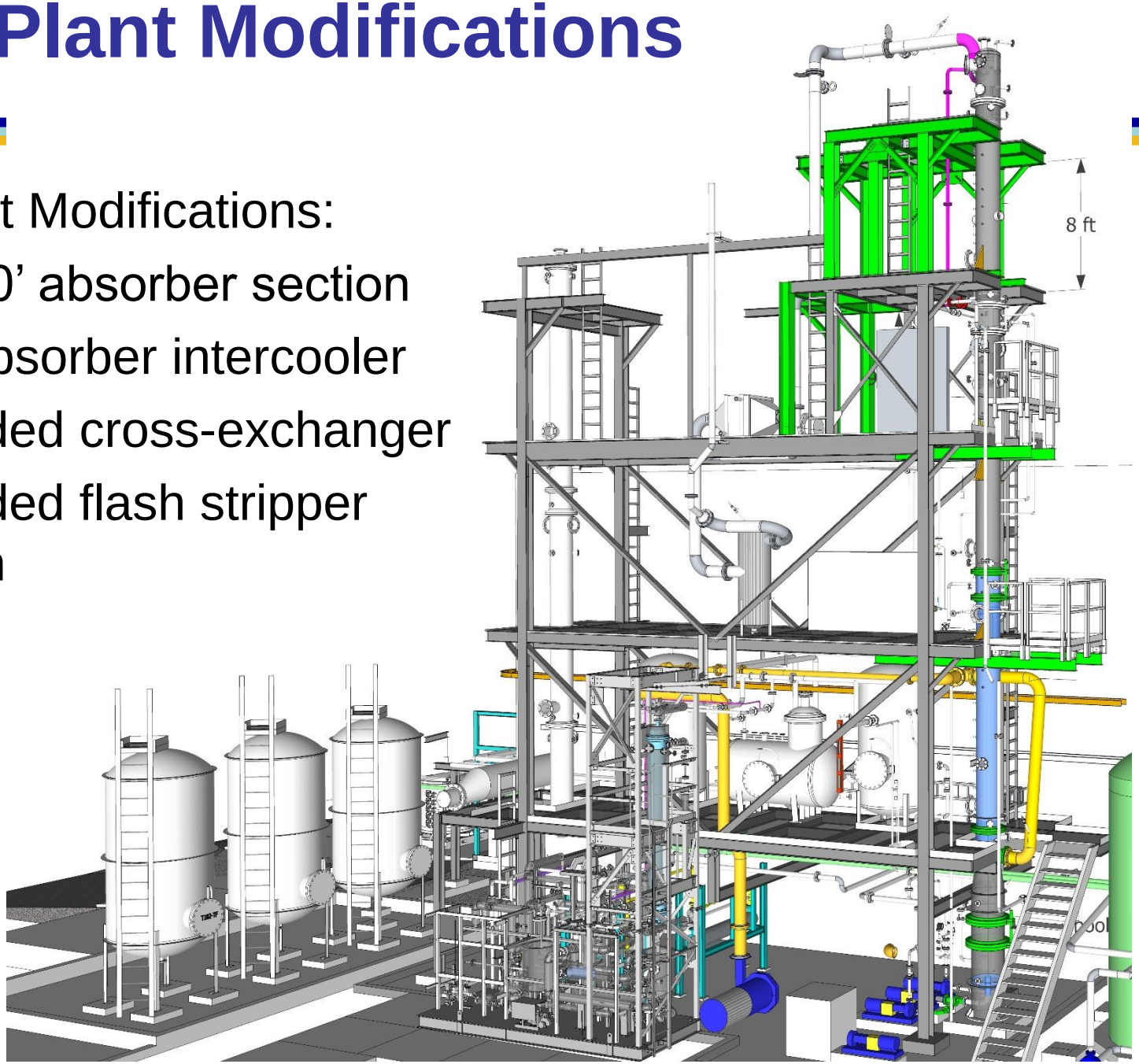
- Separations Research Program (SRP) Pilot Plant at the Pickle Research Campus (Austin, TX)
- Synthetic Flue Gas: Air/CO_2
- 18-inch diameter absorber and stripper column
- 20 feet (6.1 m) absorber packing (2 x 10-ft sections)
- Advanced Flash Stripper (AFS) skid w/cold and warm rich bypass



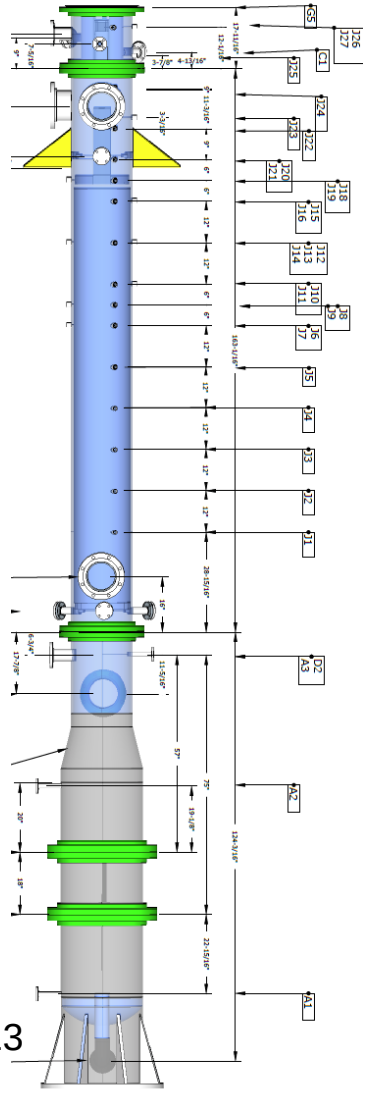
Pilot Plant Modifications

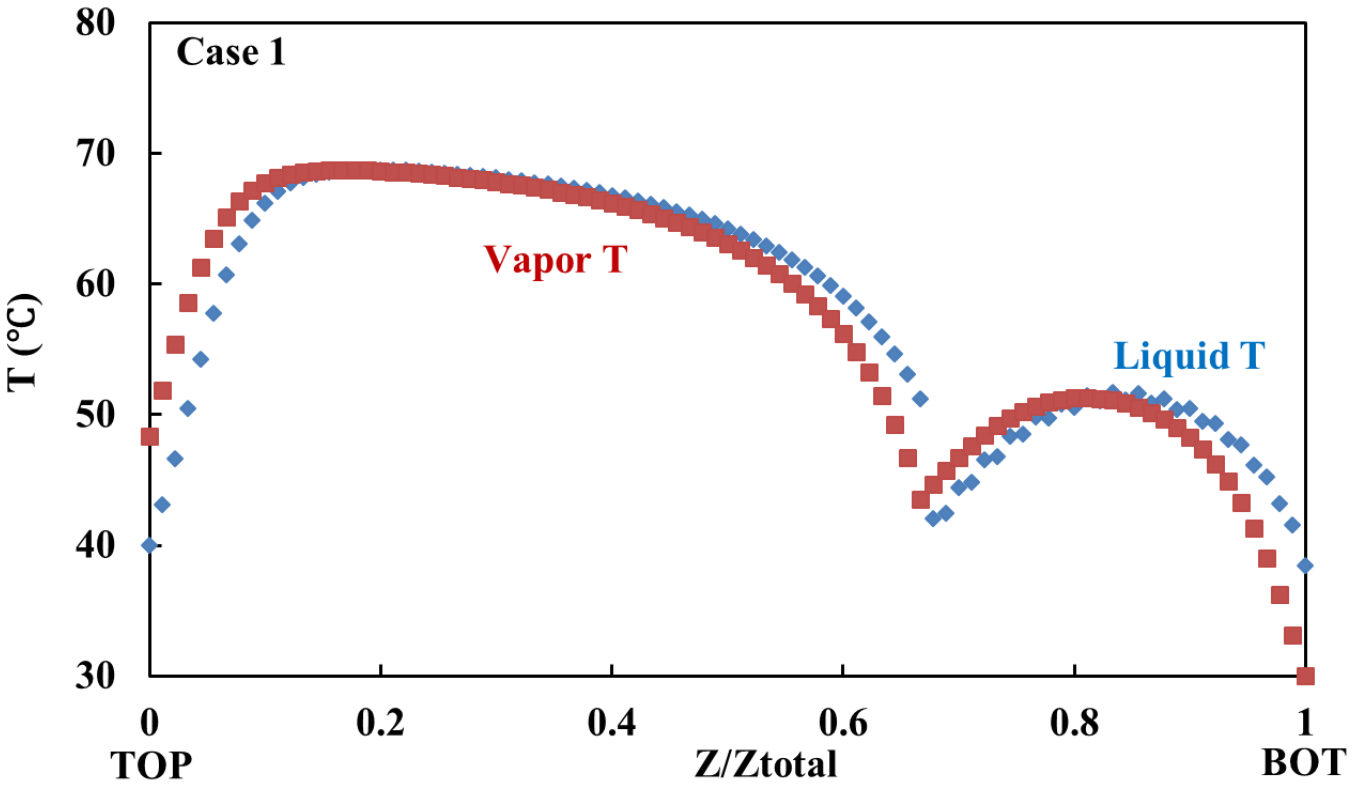
Pilot Plant Modifications:

- New 10’ absorber section
- New absorber intercooler
- Upgraded cross-exchanger
- Upgraded flash stripper column



Absorber Column Extension





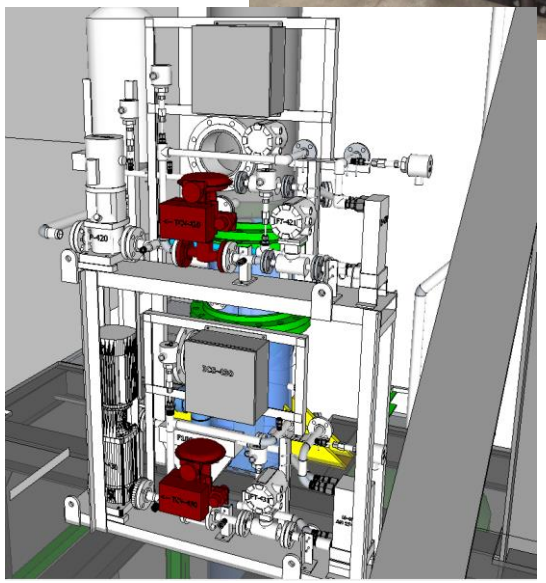
- Adds a 3rd 10-ft section of packing (30-feet total)
- Currently being fabricated

Absorber Intercooler Skid

- New in-and-out intercooler provides temperature control in absorber.
- Liquid is collected by a chimney tray at the bottom of the middle bed, cooled to 40°C and returned to the bottom section.

✓ Intercooler skid assembly complete.

❑ Awaiting installation



New Cross-Exchanger Installed

- New Alfa Laval TL10-BFS installed at the cold-rich bypass junction.
- Operating pressure upgraded to 300 psi (vs. 150 psi for old HX)

✓ System installed with connecting piping

✓ Pressure tested

❑ Awaiting insulation

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Upgraded 10-inch Stripper Column

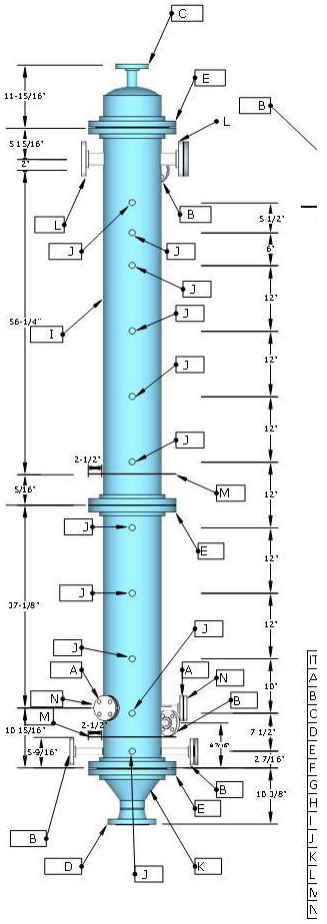
- Existing 6-inch diameter stripper cannot process the higher solvent flow rates of hybrid operation.
- A new 10-inch diameter column was designed and fabricated. Same ~2 m of packing height.

✓ Column fabricated

✓ Pressure tested

✓ Insulated

✓ Internals and supports being fabricated.



Summary of Project Findings

- The Hybrid-Parallel is the preferred hybrid configuration compared to Hybrid-Series.
- The plate-and-frame module design has significantly less pressure-drop vs. spiral wound sweep membranes.
- A solvent with higher capacity can better able take advantage of higher CO_2 content -- 2 m PZ / 3 m HMPD blend was identified as a candidate.
- The plate-and-frame membrane contactor can achieve high removal rates in simulated hybrid-parallel application.
- UT Austin identified changes to prepare the SRP Pilot Plant for hybrid-application.

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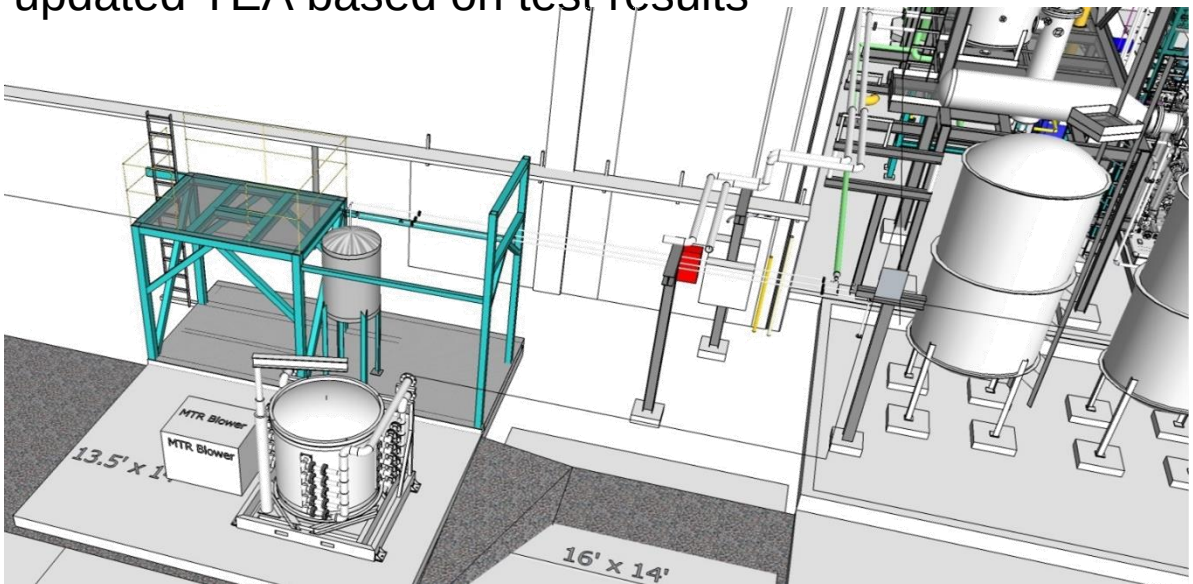
Next Steps

Budget Period 2

- Complete modifications to the SRP Pilot Plant and perform shake-down
- Operate the pilot plant under hybrid-parallel conditions
- Complete initial TEA

Budget Period 3

- Integrate MTR's plate-and-frame skid with UT Austin's SRP Pilot Plant
- Perform integrated testing campaign under hybrid-parallel conditions
- Final report and updated TEA based on test results



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- Carbon Capture Simulation Initiative

U.S. DEPARTMENT OF ENERGY

CCSI Carbon Capture Simulation Initiative

THE UNIVERSITY OF TEXAS AT AUSTIN

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Hybrid Project Team

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