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

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Hybrid Project Overview

- **Award name:** Bench-Scale Development of a Hybrid Membrane-Absorption CO_2 Capture Process (DE-FE0013118)
- **Project period:** 10/1/13 to 9/30/16
- **Funding:** $3.0 million DOE + $0.75 million cost share
- **DOE-NETL Project Manager:** Mike Mosser
- **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 simulation and initial cost study for the hybrid process, and fabricate a membrane test unit.
  - **BP2**: Upgrade the SRP pilot plant. Conduct comprehensive parametric tests of technologies separately at MTR and UT Austin, covering full range of operating conditions expected for the hybrid design. Refine simulations and prepare for operation of the integrated membrane–absorption system.
  - **BP3**: Run full parametric test program on integrated hybrid unit at UT-Austin. Use test data to refine simulations and conduct TEA.

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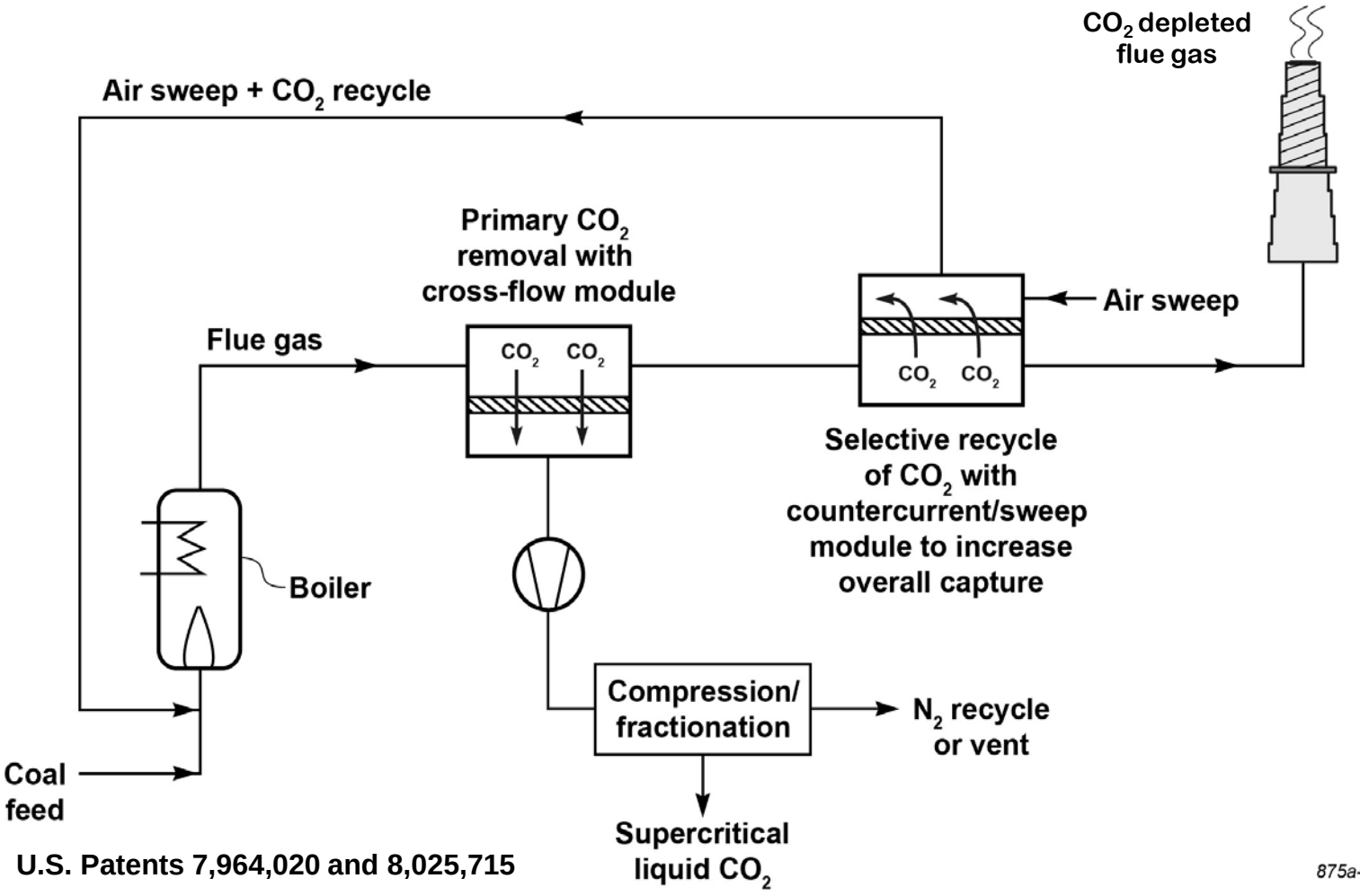
Motivation for the Hybrid Capture Process



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

875a-3d

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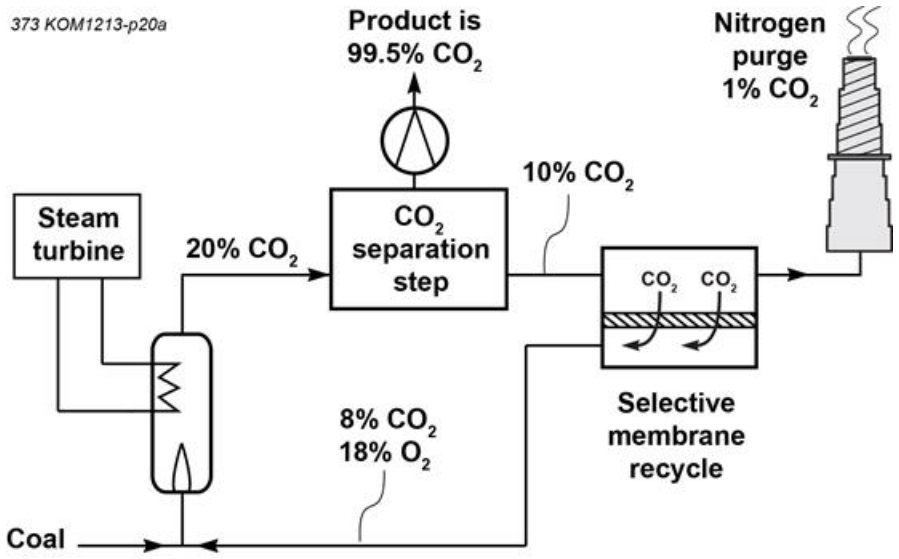
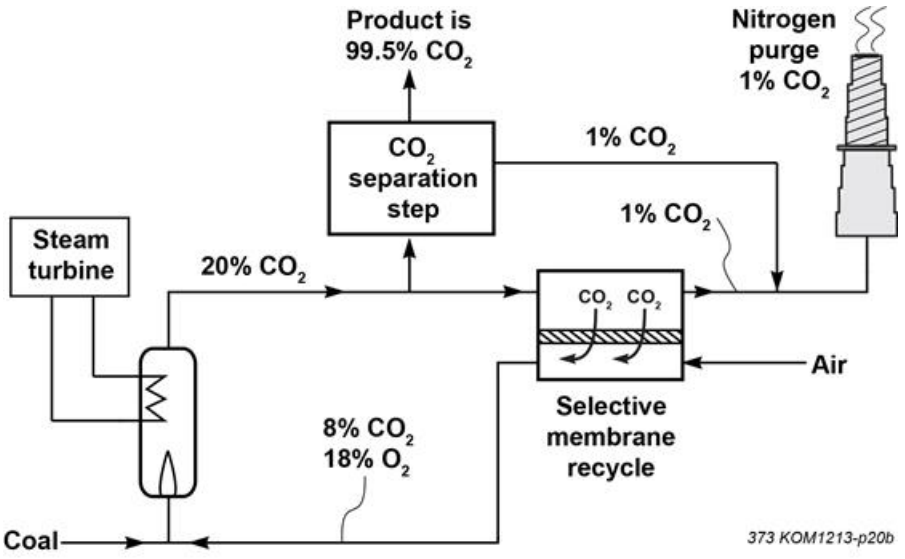
Example Hybrid Capture Systems

Hybrid-Series Arrangement



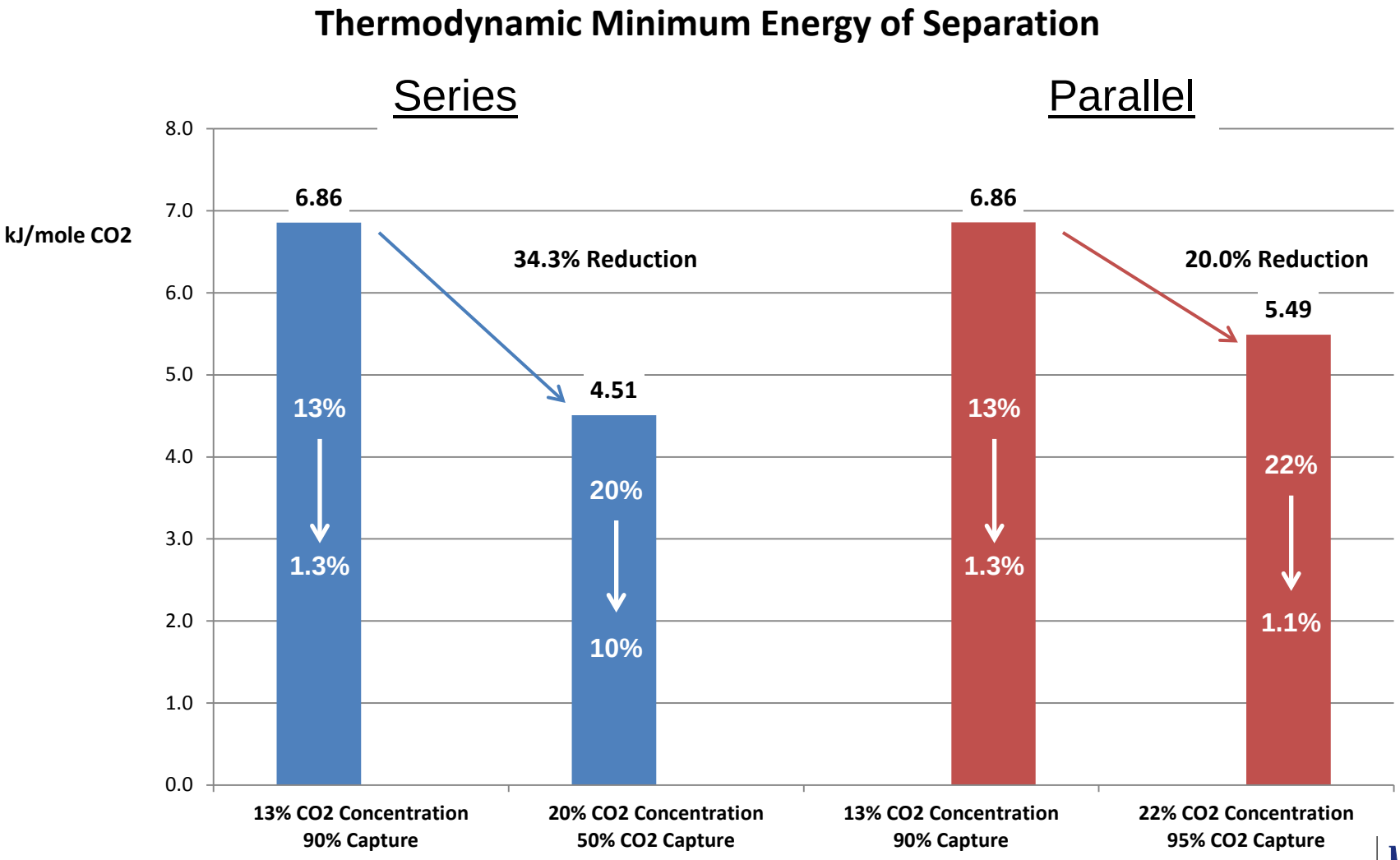
Hybrid-Parallel Arrangement



Depending on the arrangement, the selective recycle membrane can:

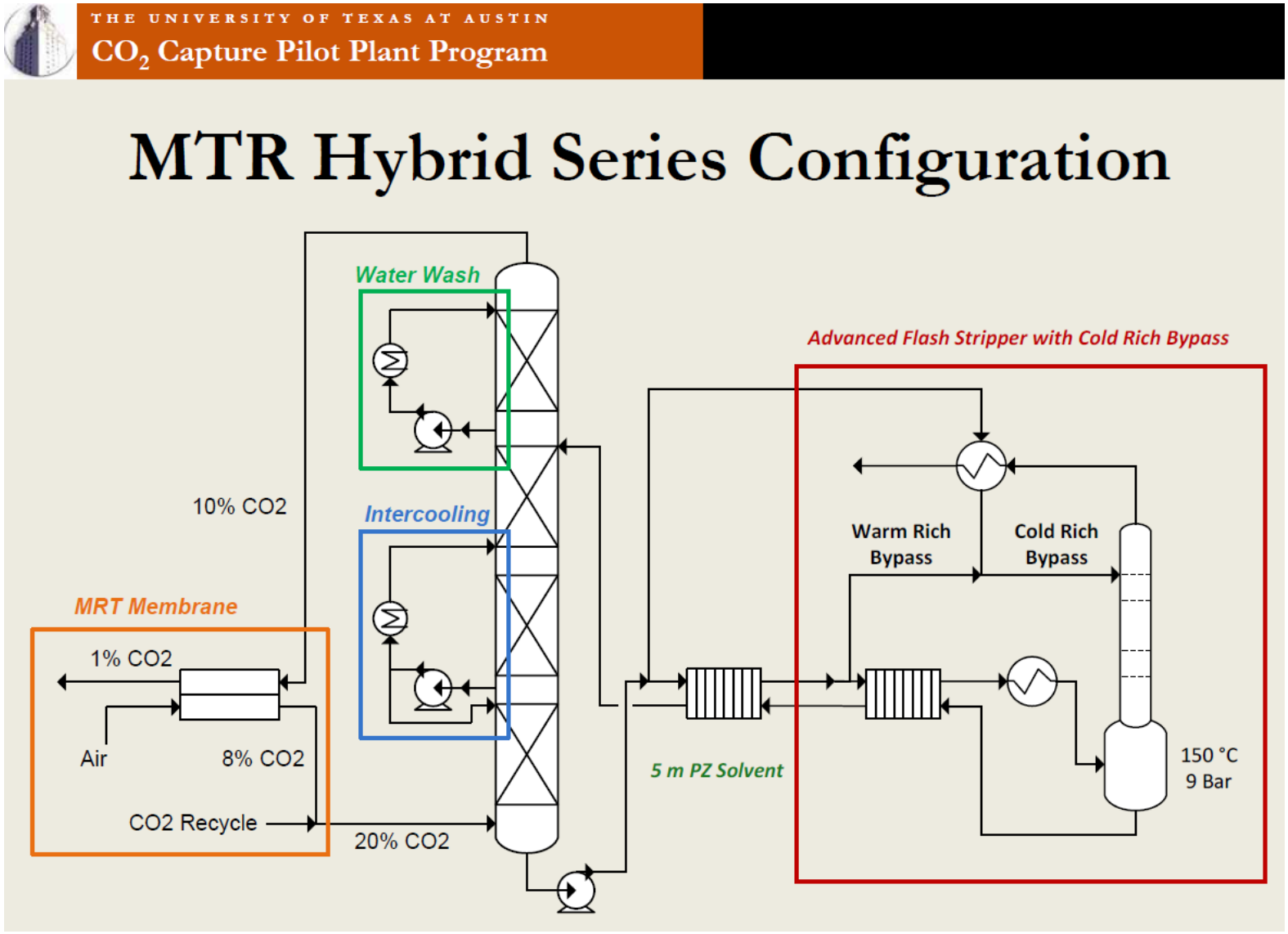
- Significantly increase the concentration of CO_2 in flue gas, and;
- Reduce the removal requirements for the capture unit (Series)
- Reduce the volume of gas sent to the capture unit (Parallel)

Minimum Energy of Separation for the Hybrid Partner

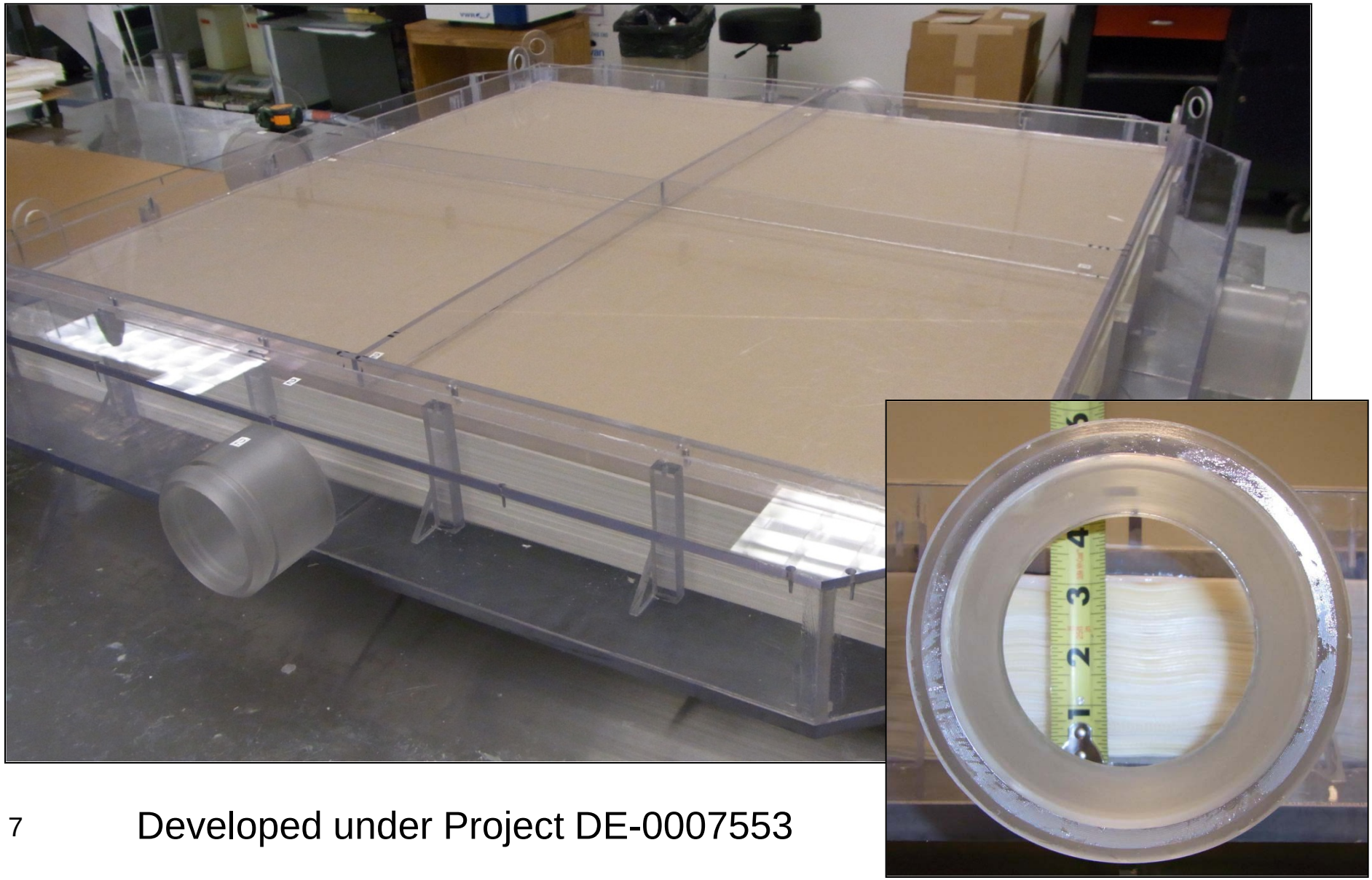


Assumes 98% CO_2 Product Purity. Does not consider CO_2 compression.

5 m Piperazine (PZ) Advanced Flash Stripper, (5 m PZ AFS)



MTR's 100 m^2 Membrane Module

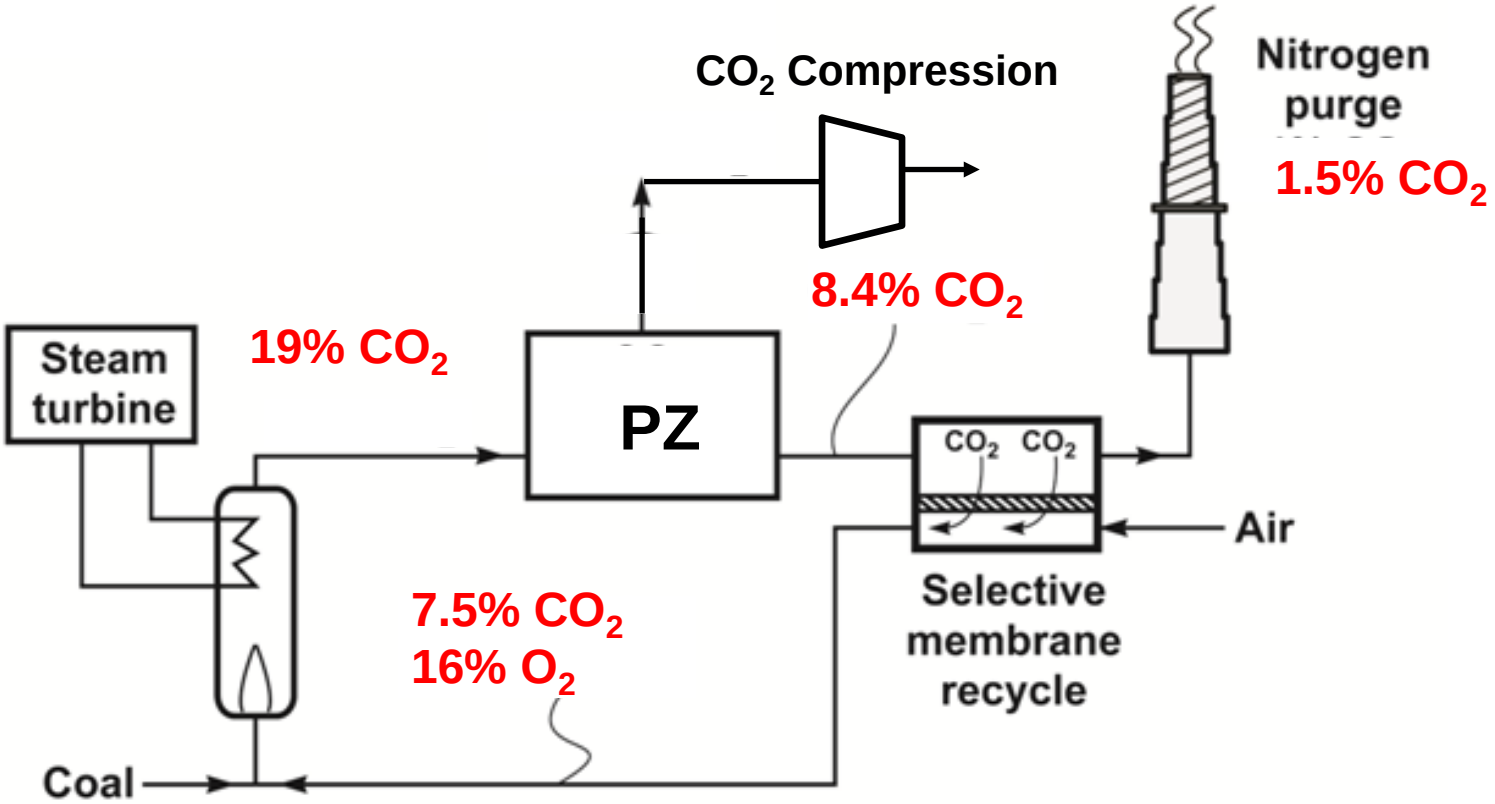


Developed under Project DE-0007553

MTR's Process Model Assumptions

- Power plant performance based on NETL Case #11.
- Fixed coal input rate.
- Fixed CO_2 generation rate.
- System CO_2 capture rate is 90% for all cases.
- Membrane: CO_2 2,000 GPU; CO_2/N_2 selectivity 50.
- Pressure drop in the feed and sweep side = 3 psi (0.2 bar)
- O_2 concentration in combustion air entering the boiler is 18% for retrofit and 17% for new build.
- Membrane is modeled in ChemCAD, PZ Capture Plant in Aspen (Independence model).

Initial Modeling of Series Hybrid With PZ (Case 13, Case 14)



90% Capture Rate for the Entire System
Absorption process removes 60% CO_2.

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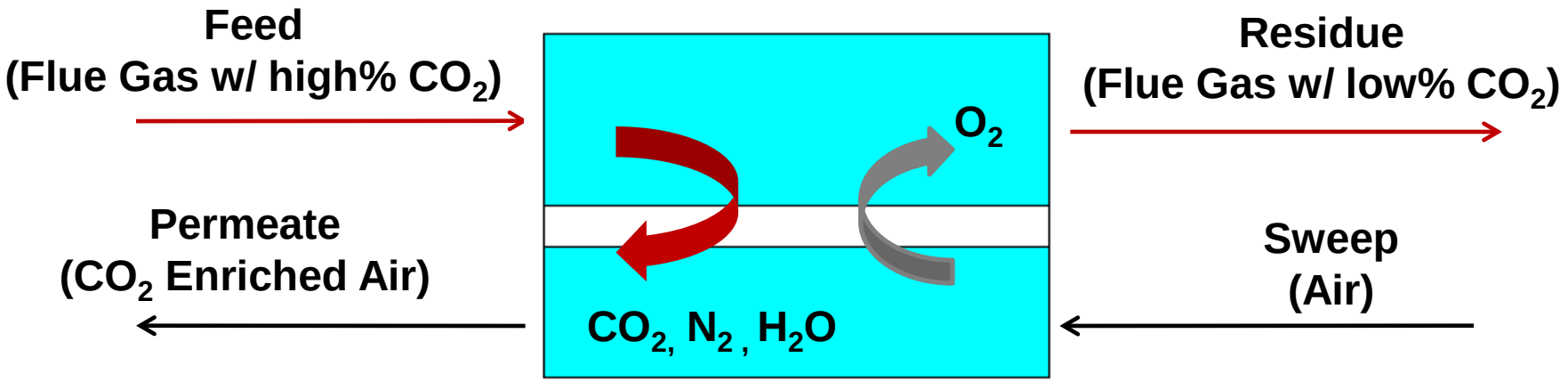
Factors Affecting O_2 Concentration in the Combustion Air



O_2 Concentration in the Combustion Air (Permeate) is a factor of:

- CO_2 dilution
- N_2 dilution
- Water dilution
- O_2 Loss

- Design condition is 18% O_2 in the combustion air for retrofit and 17% O_2 for new build applications.

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Hybrid Series Modeling Results

- The **Hybrid Series** Configuration:
  - Requires a minimum of 70% removal by amine process (original estimates were 50-60%)
  - Minimum O_2 concentration in the combustion air (17% Greenfield / 18% Brownfield) limits the CO_2 concentration in the flue gas to between 16 and 18%
  - Membrane unit is exposed to PZ vapor in the absorber overhead gas stream

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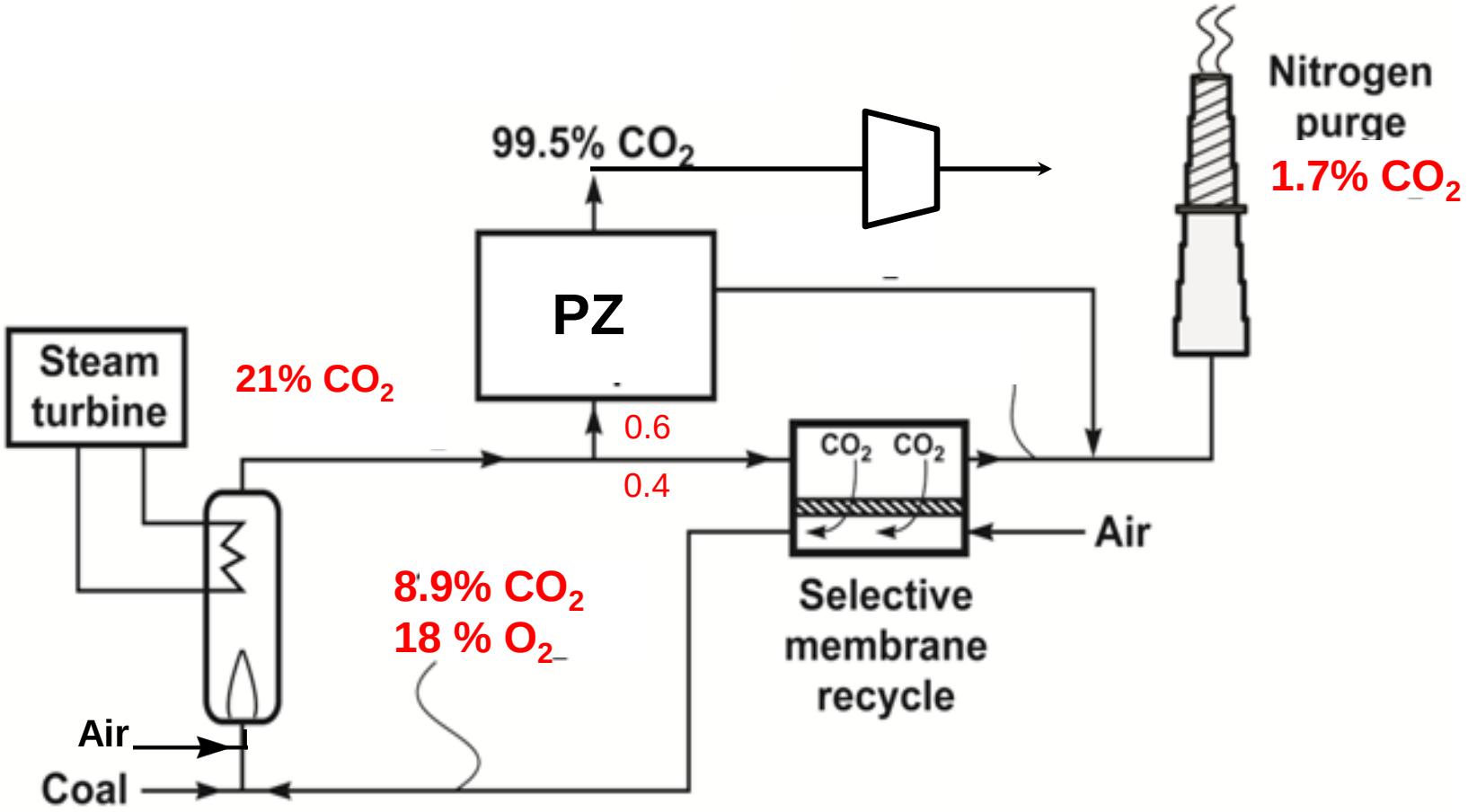
Initial Modeling of Hybrid Parallel (Case 18, Case 19)



90% Capture Rate for the Entire System

Absorption process removes 95% CO_2 from partial stream

Hybrid Parallel Modeling Results

- The **Hybrid Parallel** Configuration:
  - Requires a minimum of 53% (Case 18) to 65% (Case 19) of the flue gas directed to the absorber (balance to membrane contactor).
  - Minimum O_2 concentration in the combustion air (17% Greenfield / 18% Brownfield) *does not* limit the CO_2 concentration potential in the flue gas – 20.7% for Case 18, 24% for Case 19

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Observations

- The Hybrid-Series configuration is limited by the boiler O_2 concentration requirement.
- Hybrid-Parallel can get up to 24% CO_2 concentration in the flue gas.
- High lean loading conditions lead to high solvent circulation rates, which increase the area requirements for mass and heat transfer surfaces, thereby increasing equipment cost.
- 5 m PZ at 20%+ CO_2 concentration shows marginally higher rich loadings compared to 13% CO_2 . A higher capacity solvent would take advantage of the high inlet CO_2 concentration.

Next Steps

- Prepare updated model runs on Hybrid Parallel at 95% and 99% Absorber removal rates, and for normal and “over-stripped” lean loadings.
- Examine the same cases using 5 m PZ / 5 m MDEA (higher solvent capacity).
- Prepare the low pressure drop, plate-and-frame, membrane test skid.
- Prepare SRP for the addition of a third section of packing and water wash section.

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Acknowledgements

- Funding from DOE NETL under contracts:
  - **DE-FE0013118**
  - DE-FE0007553
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- UT's CO_2 Capture Pilot Plant Project (C2P3)

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U.S. DEPARTMENT OF ENERGY

SOUTHERN COMPANY

U.S. Department of Energy
National Carbon Capture Center

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Hybrid Project Team

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