Application of a Transformational UKy 3 Ton/Day CO_2 Capture System at a Steel Process Plant DE-FE0032133

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https://caer.uky.edu/co2capture/

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Project Objective

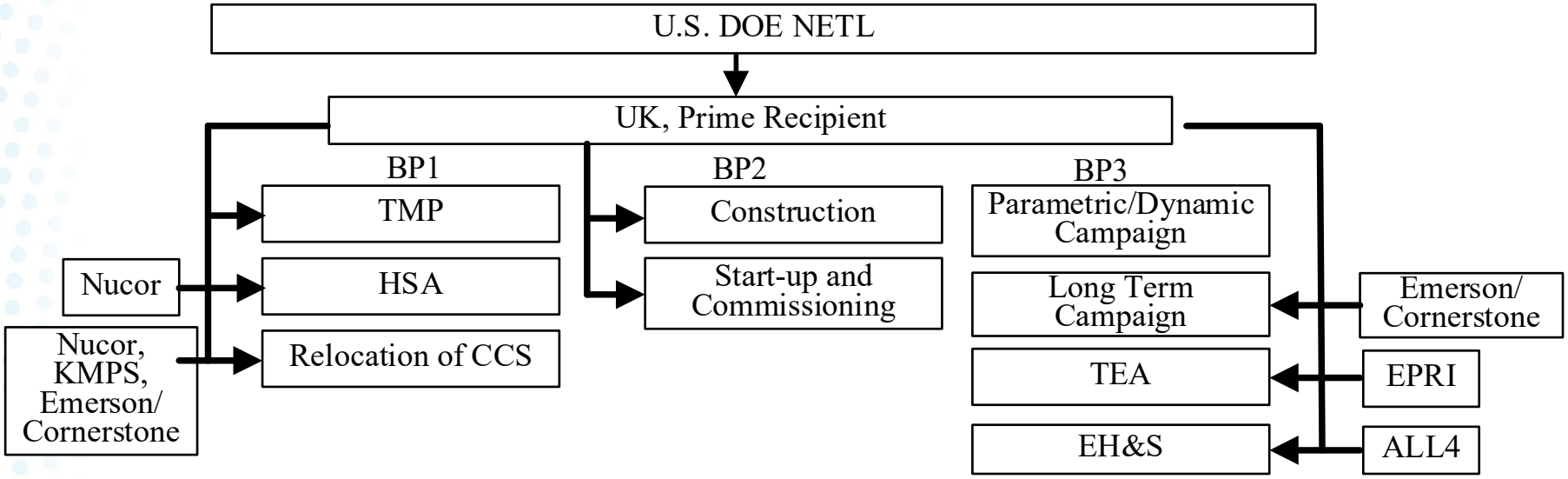
Demonstrate the UK CO_2 capture process at Nucor Steel Gallatin treating electric arc furnace evolved gas with a CO_2 concentration of ~1.5 vol%.

BP1
- Design
- Contractor selection

BP2
- Site Prep
- Module Erection
- Tie-in at Nucor

BP3
- Evaluation
- Data Analysis
- Reporting

Project Team and Funding



	DOE-NETL	Cost Share	
Total:	**$4,999,965**	**$1,250,523**	**$6,250,488**
Percent Share:	**80%**	**20%**	**100%**

Background - Development

UK Solvent

- <$5/kg chemical cost
- ~6400 experimental hours at bench and small pilot scales
- NG and coal flue gas evaluations
- 3-20 vol% CO_2 inlet concentration evaluations
- Modeled by small pilot experimentally verified Aspen Plus®
- Solvent regeneration energy as low as 1040 BTU/lb CO_2
- Make-up rate of 0.6 kg/tonne CO_2

H3-1 Solvent Campaign

H3-1 Solvent Performance: ~27% reduction in solvent regeneration energy, 35-45% reduction in circulation rate, low degradation compared to 30 wt% MEA

CCSL Solvent Campaign

CCSL Solvent Performance: ~30% reduction in solvent regeneration energy, 40% reduction in circulation rate, low degradation compared to 30 wt% MEA

CAER Solvent Campaign

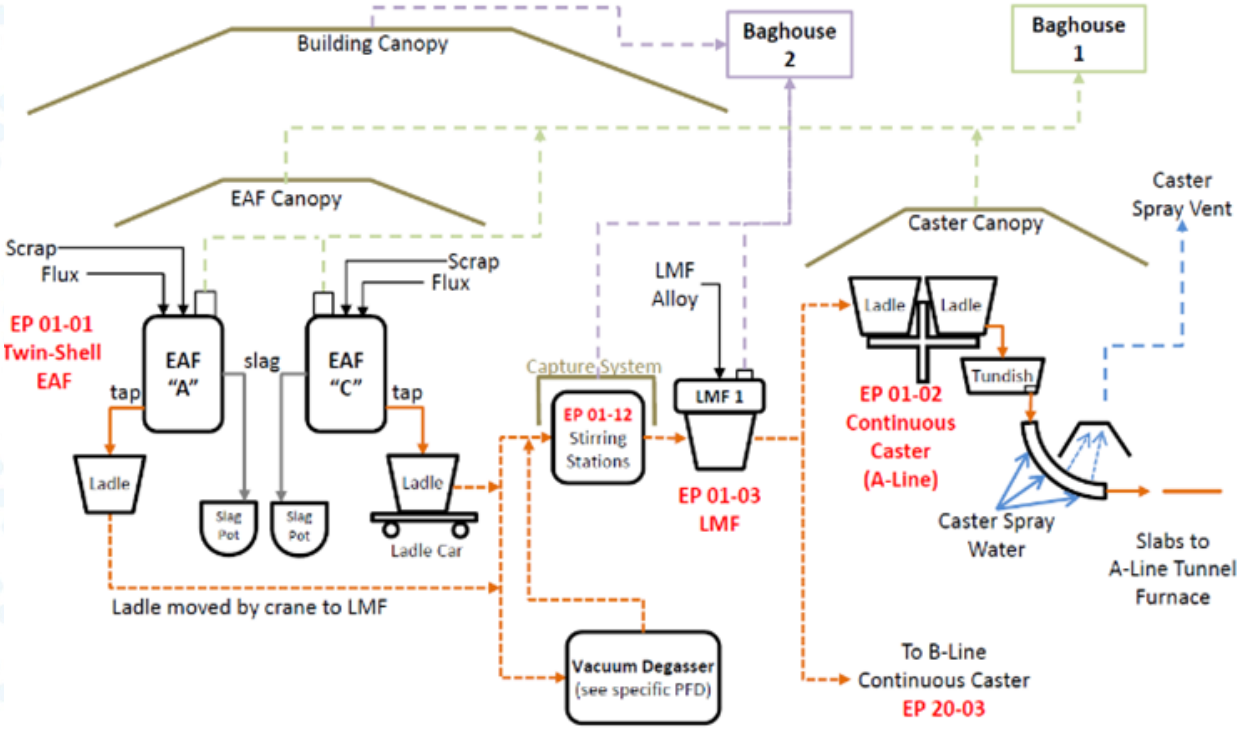
- CAER Solvent Performance: ~20% reduction in solvent regeneration energy, 30% reduction in circulation rate, low degradation compared to 30 wt% MEA
- Solvent Cost <$5/kg chemical

Process Modifications

- Absorber Temperature Control via discretized packing
- In-situ liquid redistributor
- Solvent spray with <50 µm droplets leads to 2.6-4.1X?increased CO2 absorption per unit volume
- Staged feed to Absorber and Stripper
- Heat Integration with steam cycle feedwater
- Solids circulation solvent recovery system reduces amine emissions by 50%

Background – Adaptability and Conditions

- Low CO_2 concentration ~1.5 vol%
- Low SO_2
- Low H_2O



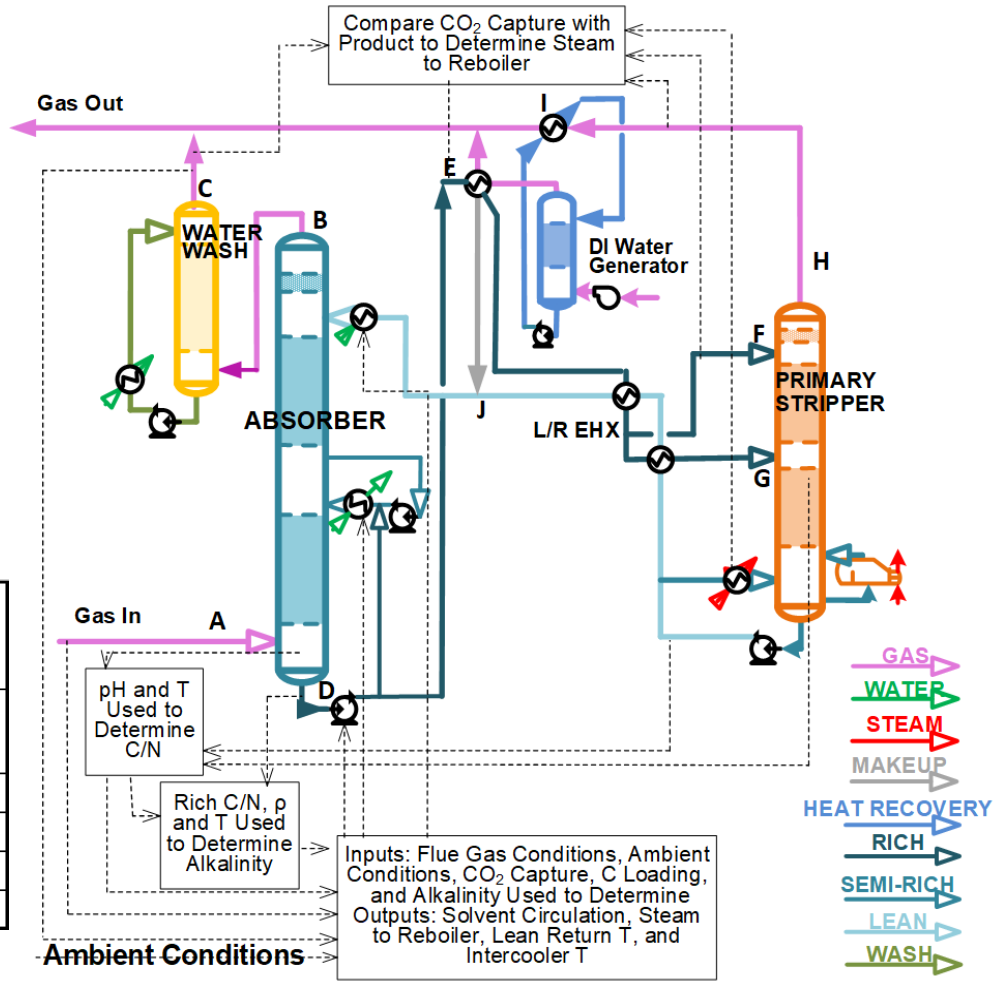
Flue Gas Conditions

Gas Component	Value
CO_2, vol%	0.5-1.5
O_2, vol%	19-20
H_2O, vol%	<5
SO_2, ppm	0.23-4.5
NO_x, ppm	1.6-5.2
N_2+Ar	Balance
Flowrate, cfm	1,000,000
Temperature, °F	80-100
Pressure, psi	14.6

Technical Approach

- Process Simplified
- Low L/G
- Specialized absorber packing
- Auto-set points for input energy minimization
- Lower specific reboiler duty via split rich stripper feed

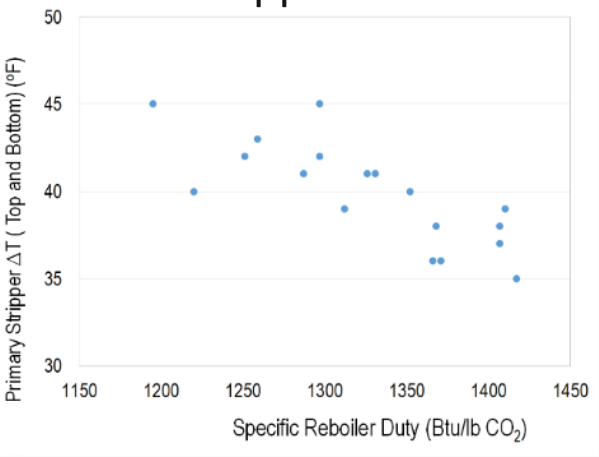
Split Flow % (Warm/ Hot)	CO_2%	Solvent Flow (lb/hr)	% Capture	BTU/lbC O_2	Lean Loading	Rich Loading
		DP (inH_2O)			Alkalinity (mol/kg)	Alkalinity (mol/kg)
20%/ 80%	4%	100.1	86.8	945	0.66	1.72
		2.3			4.906	4.874
0/100%		95.1	83.8	1073	1.09	1.89
		2.3			5.068	4.894



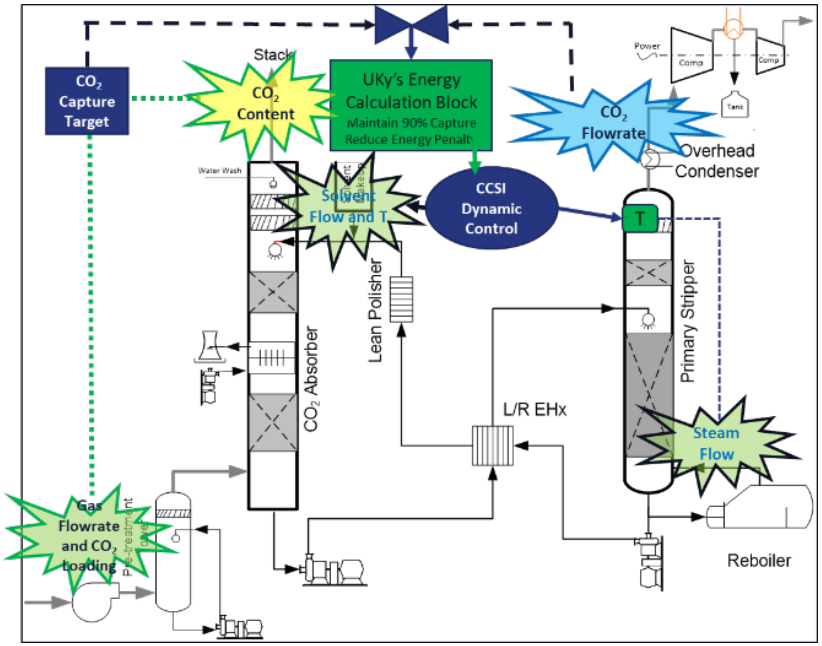
Technical Approach

Just-in-time optimal operation via feed-forward process control strategy, collaborating with Emerson

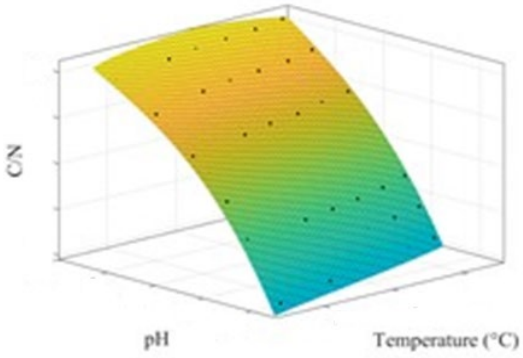
Energy Reduction with Higher Stripper ΔT



Feed Forward Control



Relationship Among pH, T and C/N



Project Milestones

Task	Milestone Title/Description	Planned Completion Date
1.0	Project Kickoff Meeting Held	8/24/2022
1.2	TMP Complete	8/24/2022
2	Host Site Agreement (HSA) Complete	10/24/2022
3	PDP Complete	10/24/2022
3.2	Boiler Procurement Decision Point Meeting	8/24/2022
3.6	General Contractor Selected	4/24/2023
4.1	Nucor Site Prepared for Installation	6/24/2023
4.3	CCS Installed at Nucor	10/24/2023
5	Test Plan Complete	10/24/2023
6	Commissioning Complete	4/24/2024
7	Parametric/Dynamic Campaign Complete (Demonstrate 95% CO_2 capture efficiency and CO_2 product stream purity of ≥95%; quantify absorber performance and reboiler duty)	9/24/2024
8	Long-term Campaign Complete (1000 hours showing optimized process conditions, dynamic stability and operability)	12/24/2024
9	TEA Complete	1/24/2025
10	EH&S Complete	1/24/2025

Project Success Criteria

Decision Point	Date	Success Criteria
Completion of BP1	4/24/2023	1) Contract in place with engineering design firm for CCS reconfiguration and relocation 2) Boiler specified and procured 3) Contract in place with general contractor for relocation of CCS
Completion of BP2	4/24/2024	1) Commissioned CCS at Nucor Steel Gallatin Site 2) Acceptance of test plan
Project Completion	4/24/2025	1) At least 2 months of engineering-scale testing campaign of three transformational CO_2 capture technologies at the Nucor Steel Gallatin Site. 2) Demonstrated ≥95% CO_2 capture efficiency 3) Demonstrated CO_2 product stream purity of ≥95% 4) Techno-economic analysis showing Cost of Capture and Cost of CO_2 Avoided, calculated for gross CO_2 captured and net CO_2 captured 5) Attainment of TRL 6 of the three proposed transformational CO_2 capture technologies

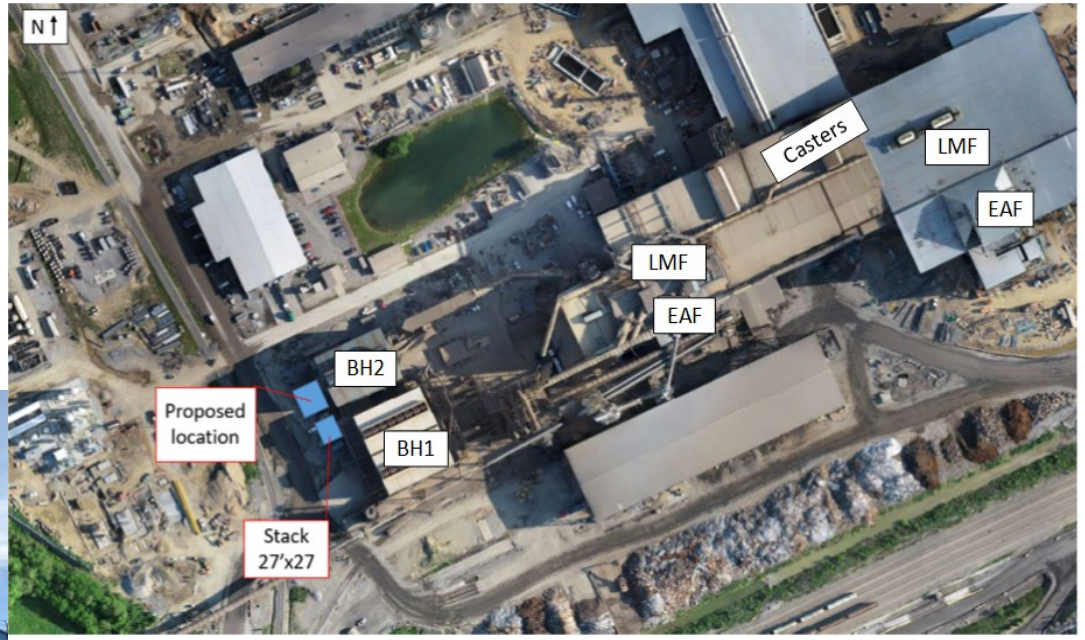
Progress: Relocation Activities

BP1 Task		Progress
2	Host Site Agreement (HSA)	Communication between UK and Nucor
3	Unit Reconfiguration and Relocation Planning	
3.1	Reconfiguration	Quote for CO_2 capture unit reconfiguration received from KMPS. Quote for BOP and bid package preparation received from B&M.
3.1.1	Absorber Internals	
3.1.2	Split Rich Stripper Feed	
3.1.1	Advanced Control Strategy	
3.1.4	Process Simplification	
3.2	Steam Generator Procurement	
3.3	Site Survey and Prep	
3.6	General Contractor Selection	Initial meeting with UK Purchasing held.
3.7	HAZOP	

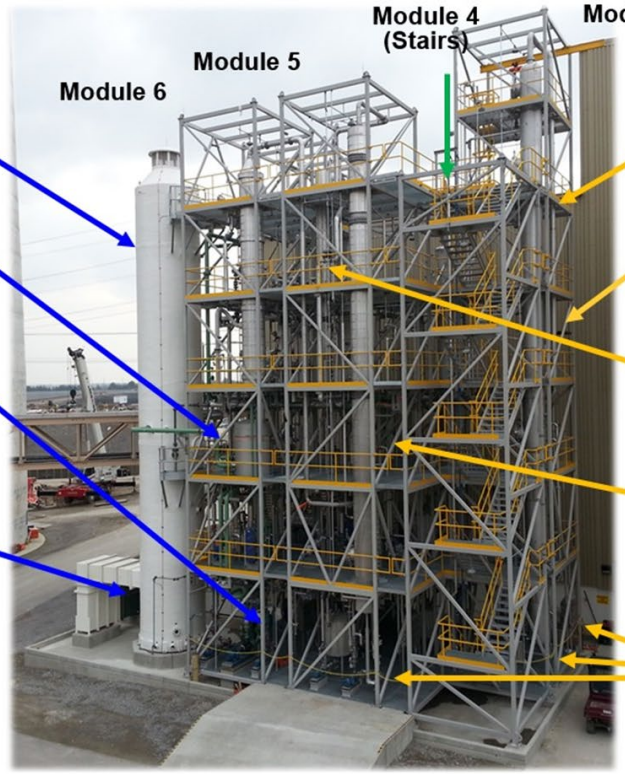
Capital Project request defined by UK is in the process

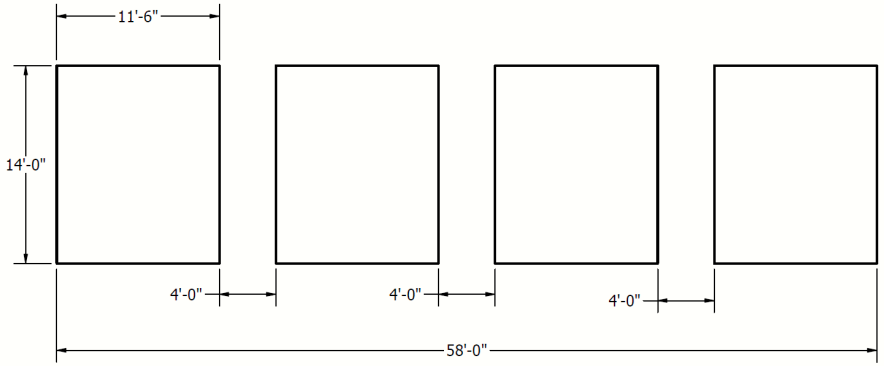
- Board of Trustee approval
- Establishing plant account
- Issuing RFP for engineering firm selection
- Solicit public bid for BOP preparation and module relocation

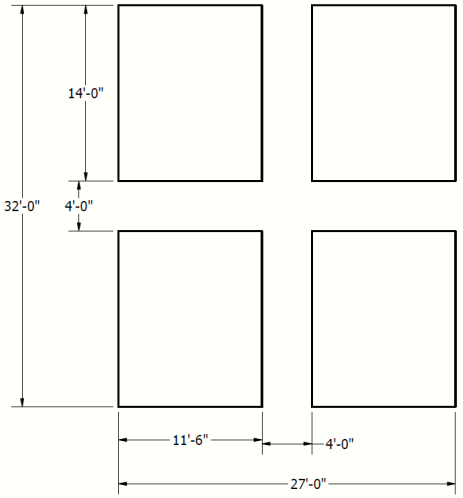
Location at Nucor Steel Gallatin



Module Arrangement







Summary – Expected Output

- Firsthand experience and knowledge on low concentration CO_2 capture – performance, solvent management and dynamic operability
- Control strategy automatically maintains the target CO_2 capture efficiency while continuously minimizing the solvent regeneration energy.
- Full-scale deployment if the post-combustion CO_2 capture is feasible and cost effective

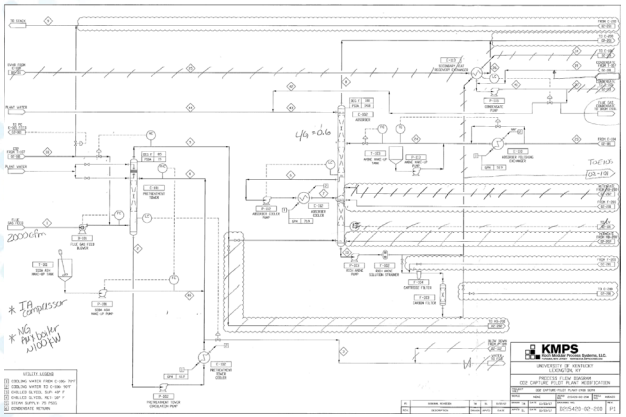
Capture Process Simplification and Relocation

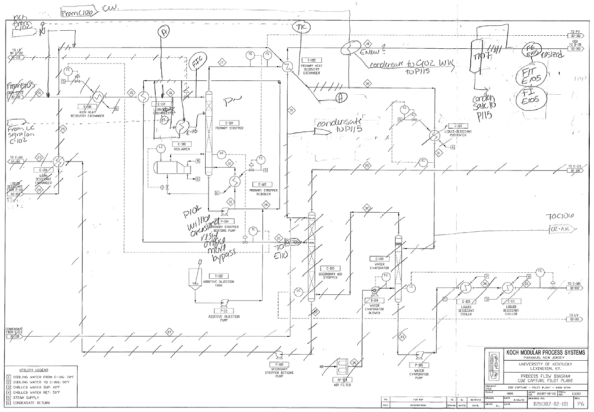
Update: PFDs, P&IDs, utility summary, 3-D model, piping isometrics, BOM, piping support details, heat tracing, stripper lead sheet for nozzle modification

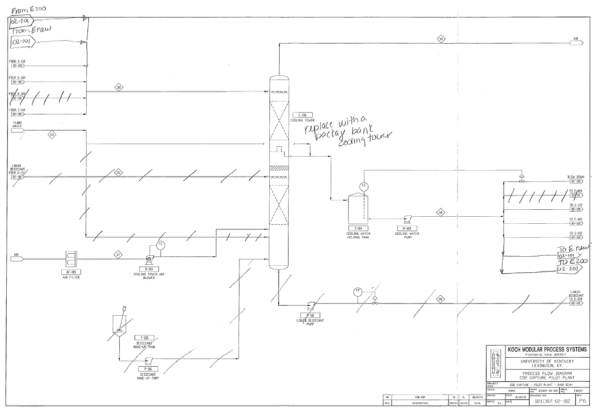
Evaluate equipment sizing: pumps, P&F heat exchangers, B-101 with new specification if required

Specify: package cooling tower, air compressor, steam boiler,

Verify: in-line instrumentation for lower L, PSV relief scenarios







Acknowledgements

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EPRI: Abhoyjit Bhown

Emerson/Cornerstone: Vigen Biglari

ALL4: Clayton Whitney

Appendix: Gantt Chart

Task Name	Start	Finish
1. Project Management and Planning	Mon 4/25/22	Thu 4/24/25
1.1. PMP	Mon 4/25/22	Tue 5/24/22
1.2. TMP	Mon 4/25/22	Wed 8/24/22
Budget Period 1	**Mon 4/25/22**	**Mon 4/24/23**
2. HSA	Mon 4/25/22	Mon 10/24/22
3. Relocation of Engineering Scale CCS	Mon 4/25/22	Mon 4/24/23
3.1. Reconfiguration	Mon 4/25/22	Mon 4/24/23
3.1.1. Absorber Internals	Mon 4/25/22	Wed 8/24/22
3.1.2. Split Rich Stripper Feed	Mon 4/25/22	Wed 8/24/22
3.1.3. Advanced Control Strategy	Mon 4/25/22	Wed 8/24/22
3.1.4. Process Simplification	Mon 4/25/22	Wed 8/24/22
3.2. Boiler	Mon 4/25/22	Wed 8/24/22
3.3. Site Survey and Preparation	Mon 4/25/22	Mon 4/24/23
3.4. Deconstruction and Removal Planning	Mon 4/25/22	Mon 10/24/22
3.5. Shipping Preparation	Mon 4/25/22	Mon 10/24/22
3.6. General Contractor Selection	Tue 10/25/22	Mon 4/24/23
3.7. HAZOP Evaluation	Mon 8/1/22	Wed 8/31/22
Budget Period 2	**Tue 4/25/23**	**Wed 4/24/24**
4. Construction	Tue 4/25/23	Tue 1/23/24
4.1. Foundation	Tue 4/25/23	Sat 6/24/23
4.2. Decommissioning and Shipping	Sun 6/25/23	Thu 8/24/23
4.3. Installation	Fri 8/25/23	Tue 10/24/23
4.4. Tie-ins	Wed 10/25/23	Wed 1/24/24
5. Test Plan	Tue 4/25/23	Tue 10/24/23
6. Start-up and Commissioning	Tue 4/25/23	Wed 4/24/24
6.1. Commissioning Plan	Tue 4/25/23	Tue 10/24/23
6.2 Start-up and Commissioning	Thu 1/25/24	Wed 4/24/24
Budget Period 3	**Thu 4/25/24**	**Thu 4/24/25**
7. Parametric/Dynamic Campaign	Thu 4/25/24	Tue 9/24/24
7.1. Absorber Packing Performance	Thu 4/25/24	Sat 8/24/24
7.2. Reboiler Specific Duty	Sun 8/25/24	Tue 9/24/24
8. Long-term Campaign	Wed 9/25/24	Tue 12/24/24
8.1. System Dynamic Stability and Operability	Wed 9/25/24	Thu 10/24/24
8.2. Reboiler Specific Duty Minimization	Fri 10/25/24	Sun 11/24/24
8.3. Packing Operability under Cyclic Operating Environment	Mon 11/25/24	Tue 12/24/24
9. TEA	Thu 4/25/24	Thu 4/24/25
9.1. Modeling	Thu 4/25/24	Thu 10/24/24
9.2. Equipment Sizing	Fri 10/25/24	Tue 12/24/24
9.3. Analysis	Wed 12/25/24	Mon 3/24/25
10. EH&S Risk Assessment	Thu 4/25/24	Thu 4/24/25

Appendix: Organizational Chart