Application of A Heat-Integrated Post-combustion CO_2 Capture System with Hitachi Advanced Solvent into Existing Coal-Fired Power Plant

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Outline

- Project Overview
  - Team and funding
  - Objective
  - SOW
  - Test site
- The facts of slipstream
  - Development history
  - System feature
  - Test site information
  - Experimental plan
  - Slipstream apparatus

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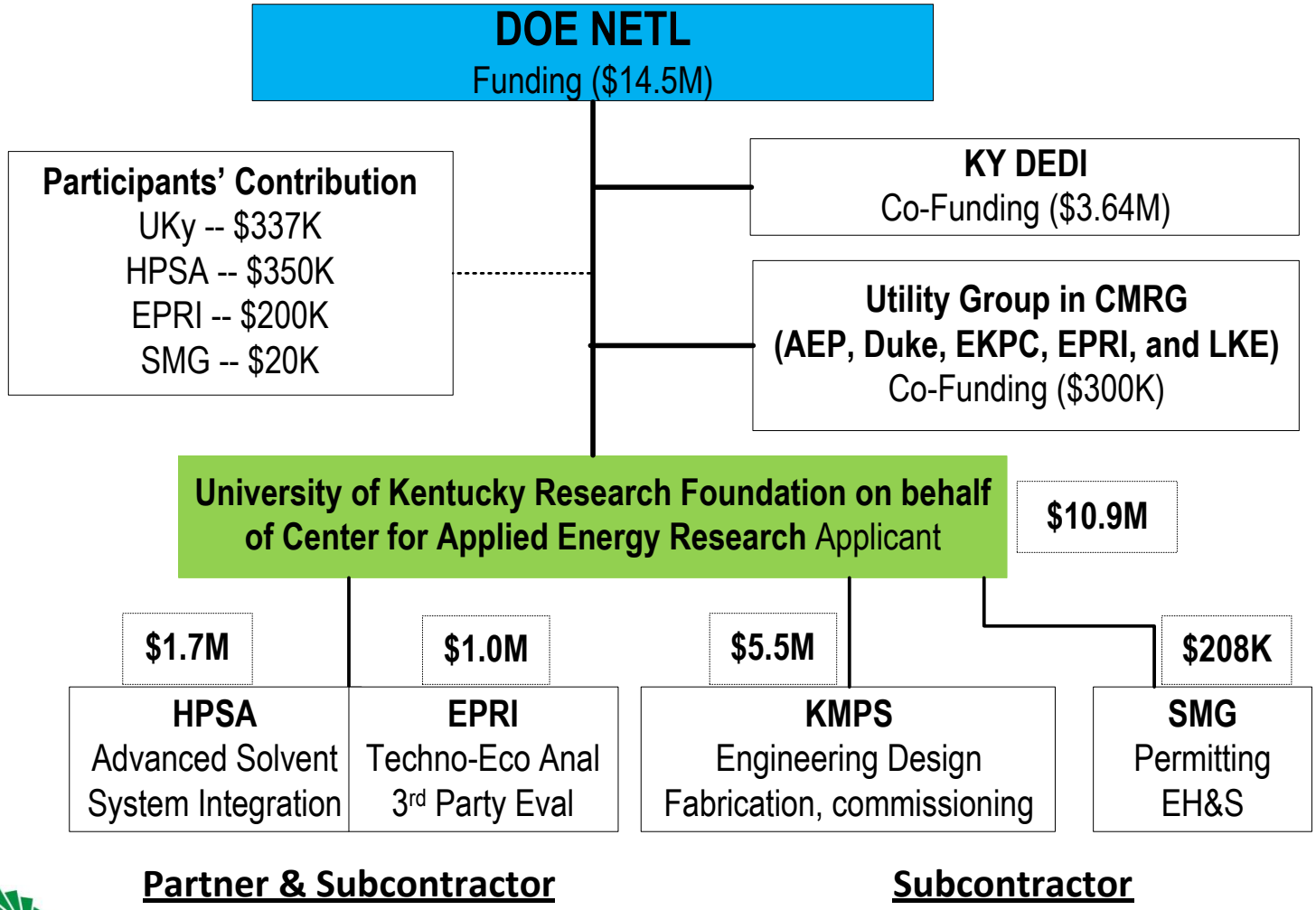
Team and Funding Structure



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Objectives

1) To demonstrate a heat-integrated post-combustion CO_2 capture system with advanced solvent;
2) To gather data on solvent degradation, water management as well as other information during the long-term verification runs;
3) To provide scale-up data and design information for commercial-scale projects;
4) To collect information/data on material corrosion and identify appropriate materials for a 550 MWe commercial-scale carbon capture plant;

What will We Do?

- The design, start-up/commissioning of a 2MWth test facility (**1400 cfm**);
- Parametric investigation and long-term verification;
- New corrosion resistance coatings for material used in CCS system (access ports needed in scrubber and stripper areas)
- Solvent degradation (liquid product and gaseous emissions from CCS)
- A series of transient tests to quantify the ability of the carbon capture system to follow load demand.

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Test Site

- Located at 815 Dix Dam Rd, Harrodsburg, KY 40330
- 40 miles from UKy-CAER

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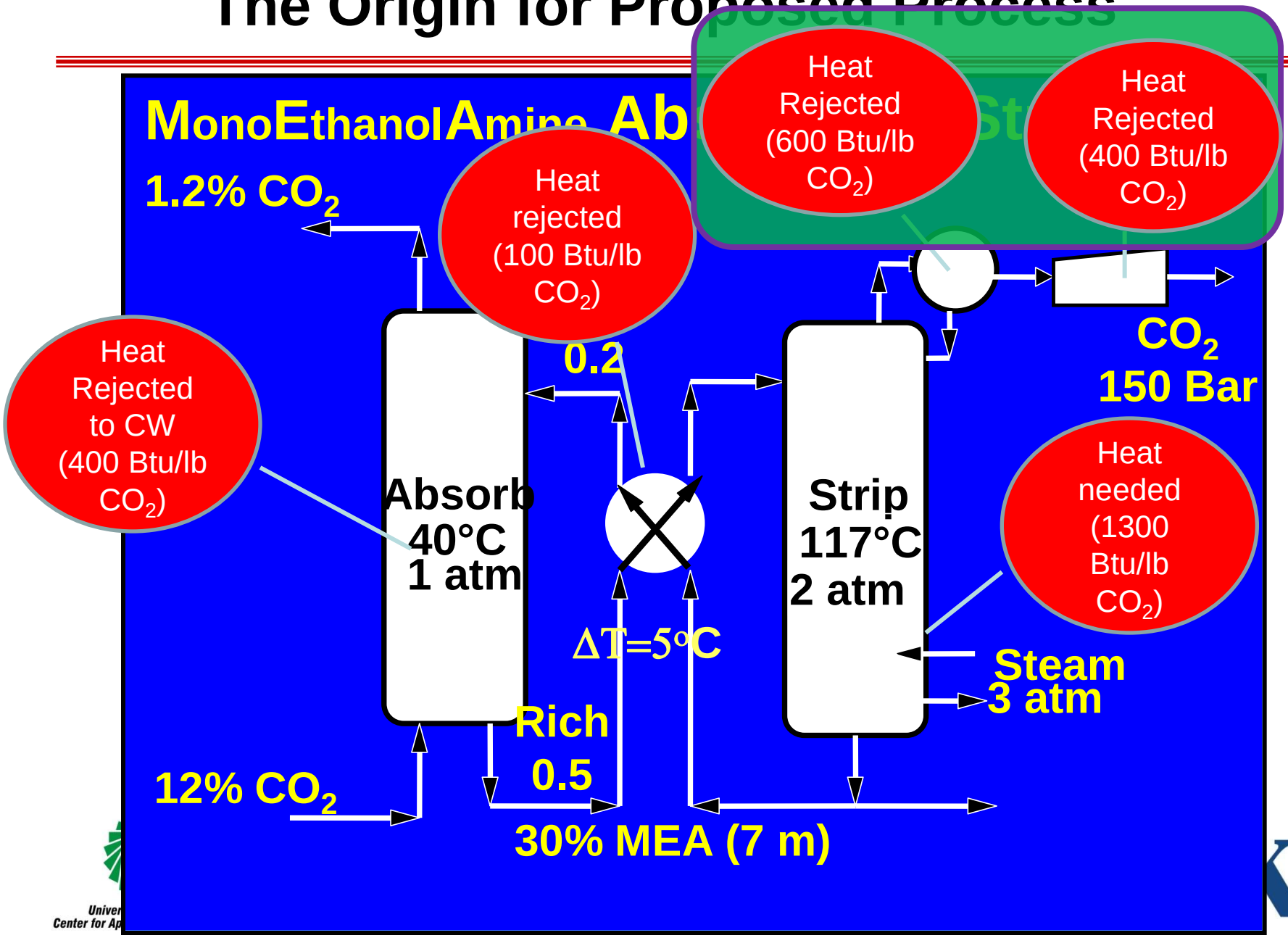
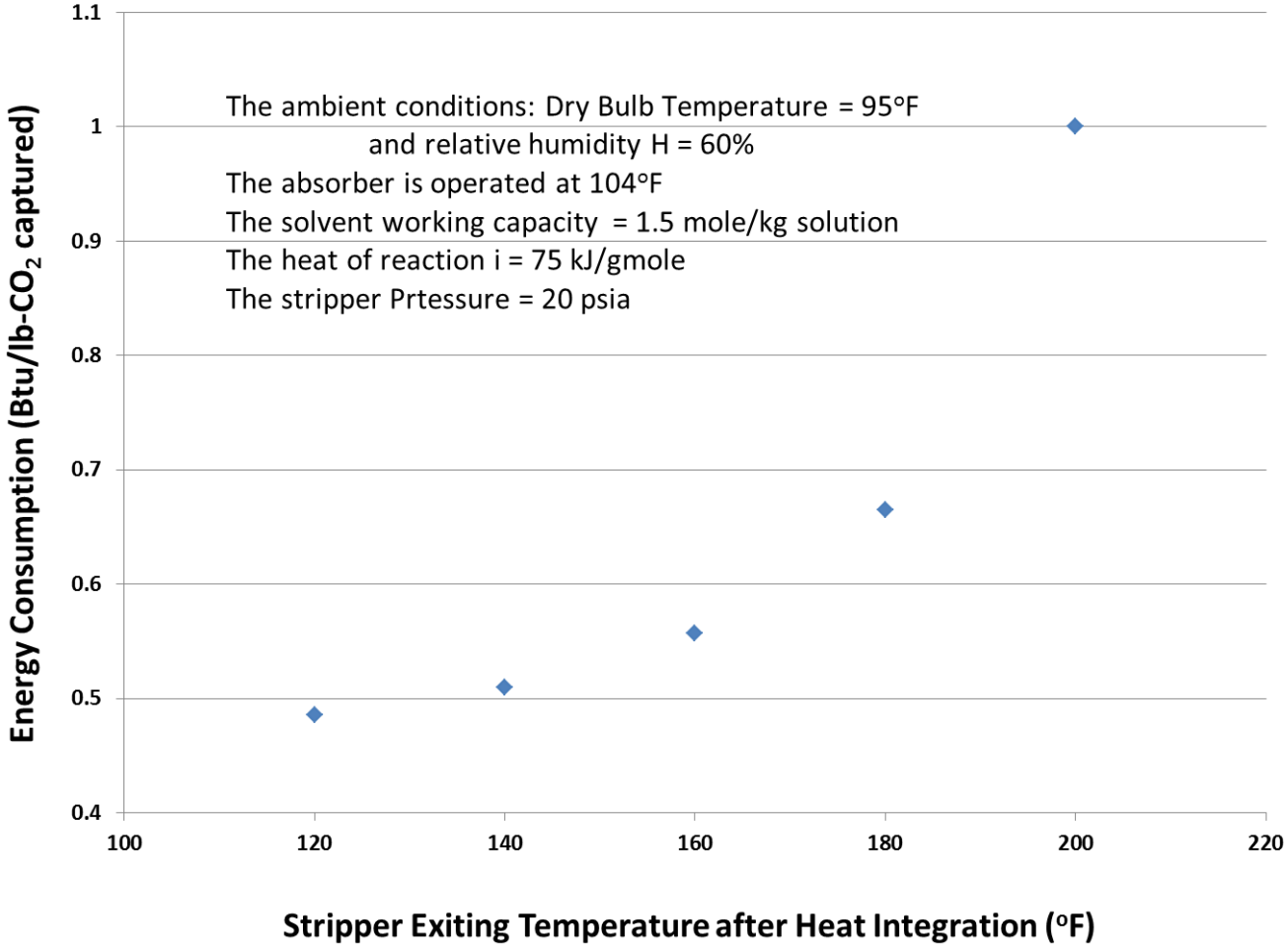
The Origin for Proposed Process



Background – Heat Recovery from Overhead Condenser



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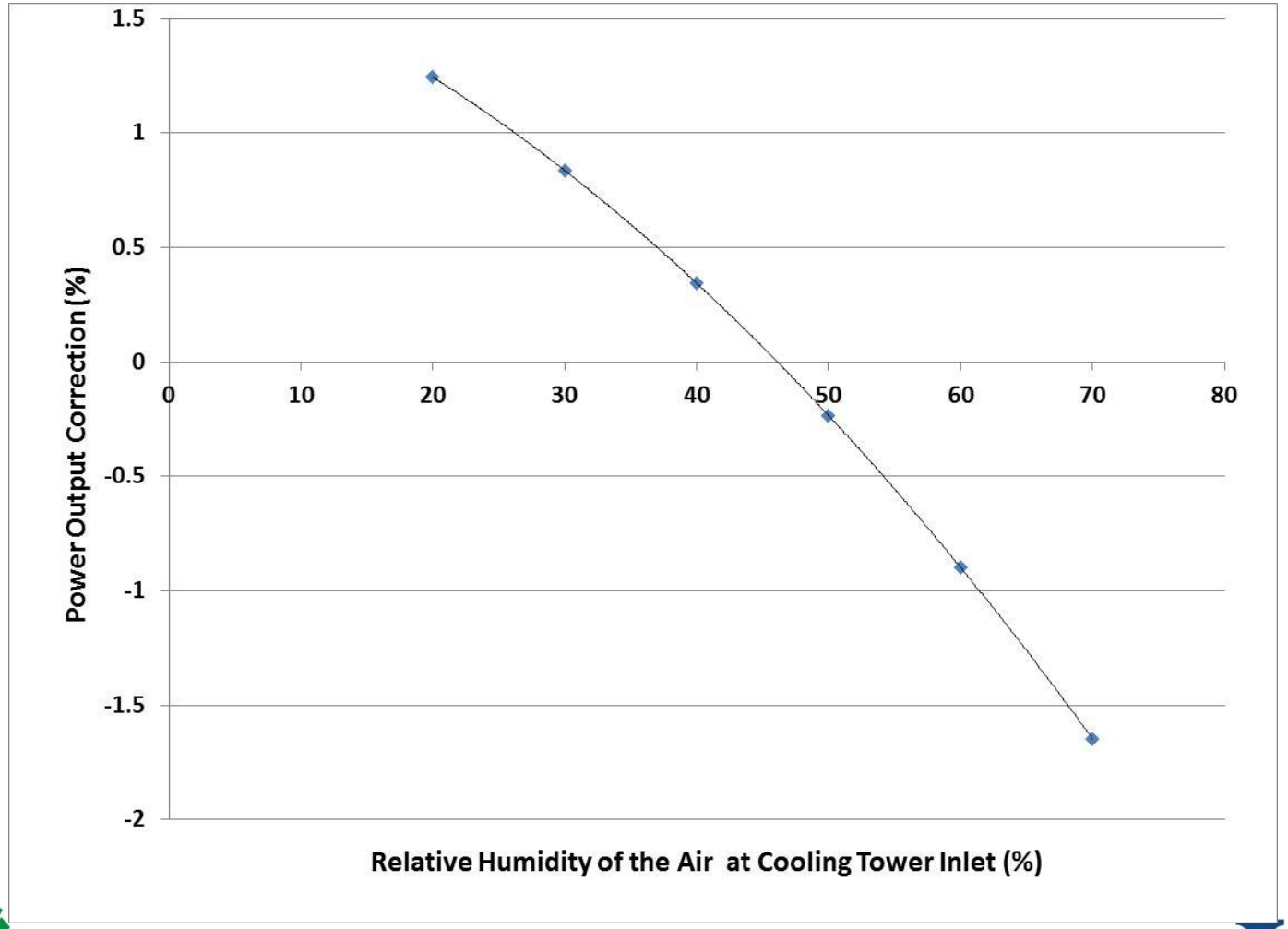
Relative Humidity on Steam Turbine Output Correction



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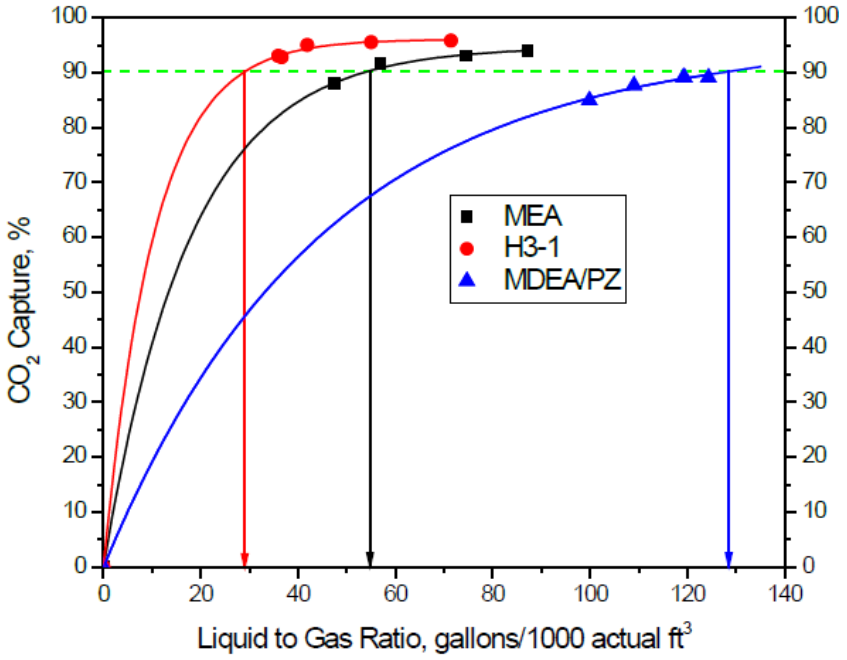
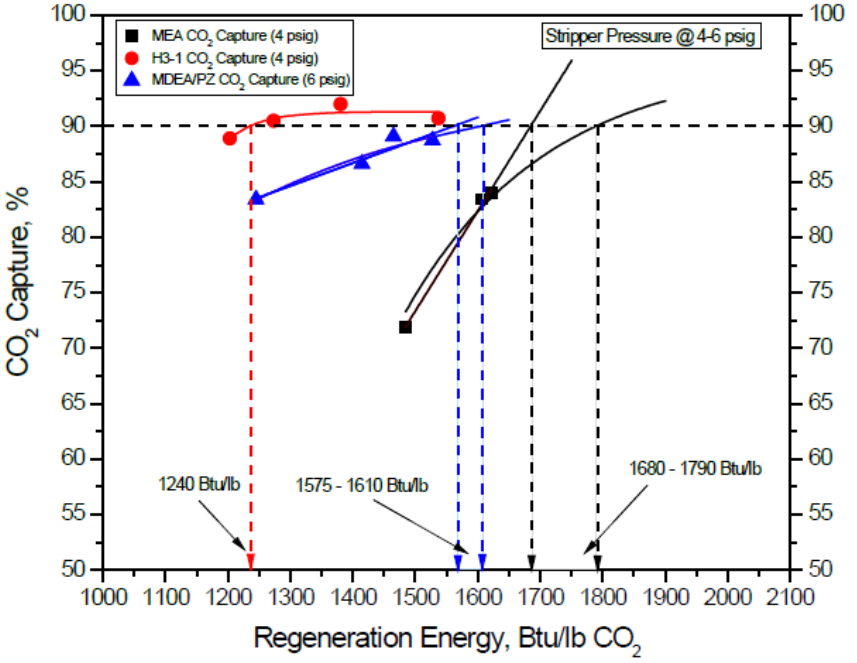
Advanced Solvent (H3-1)





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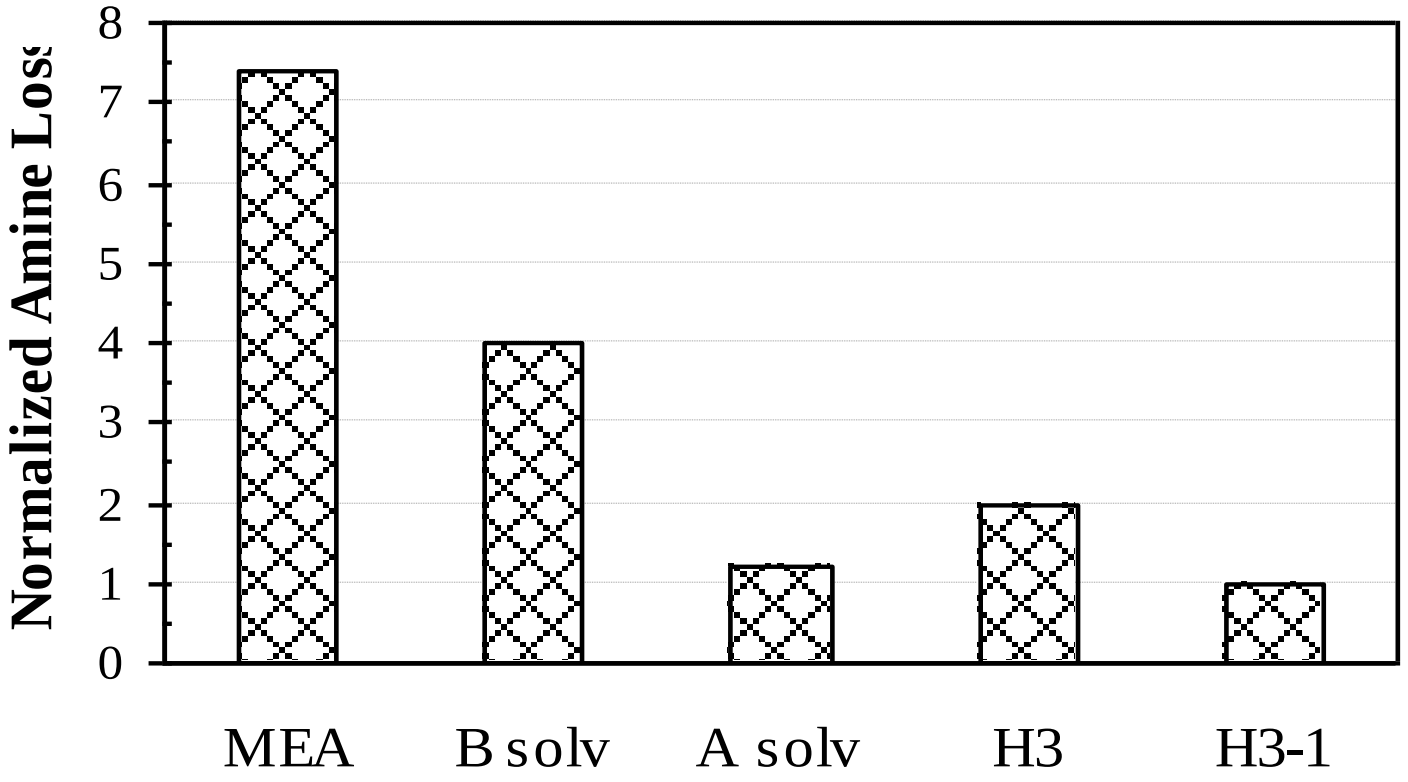

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Corrosivity of H3-1

	Temperature (°C)	Corrosion rate (mmpy)	
Solvent		**H3-1**	**5 M MEA**
Carbon steel A106	**40**	**UN**	**0.79**
	90	**0.350**	**4.97**
Stainless steel 304	**40**	**UN**	**UN**
	90	**0.104**	**0.187**

UN – within the uncertainty of instrument used

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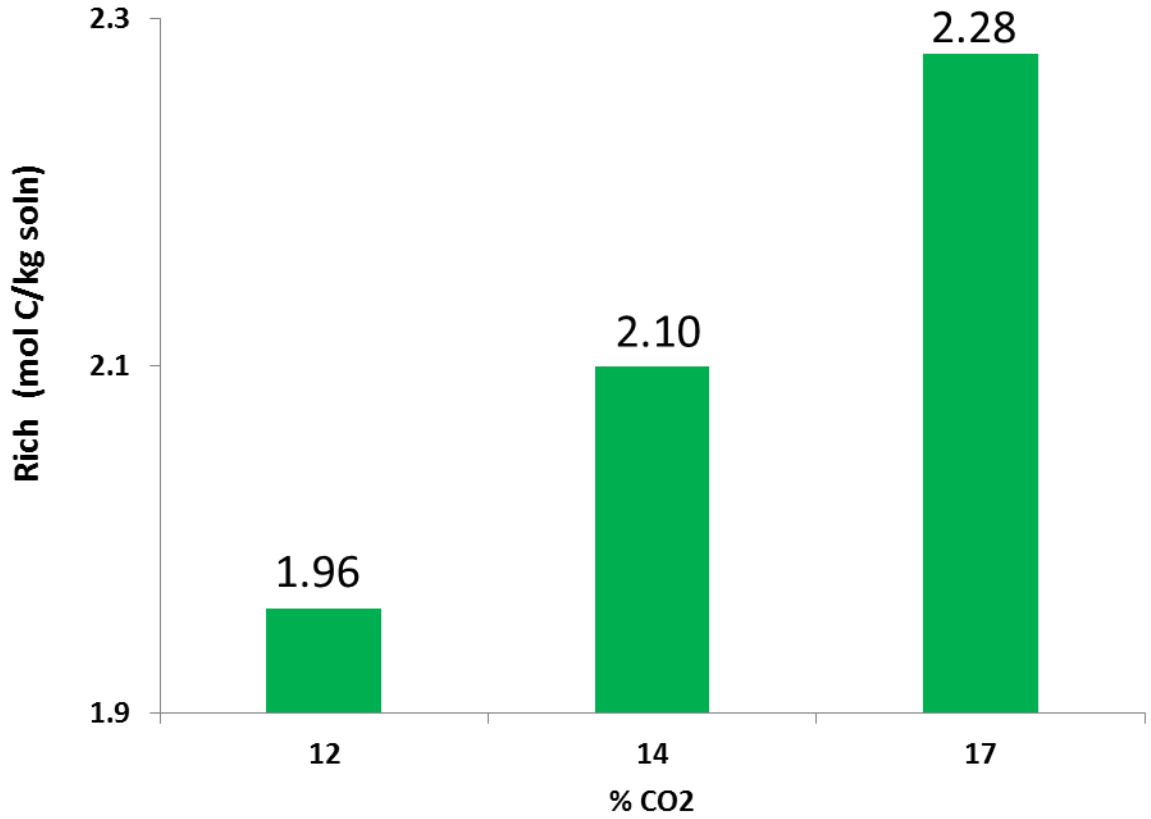
The Effect of CO_2 Concentration at Absorber Inlet on Carbon Loading in Rich Solution



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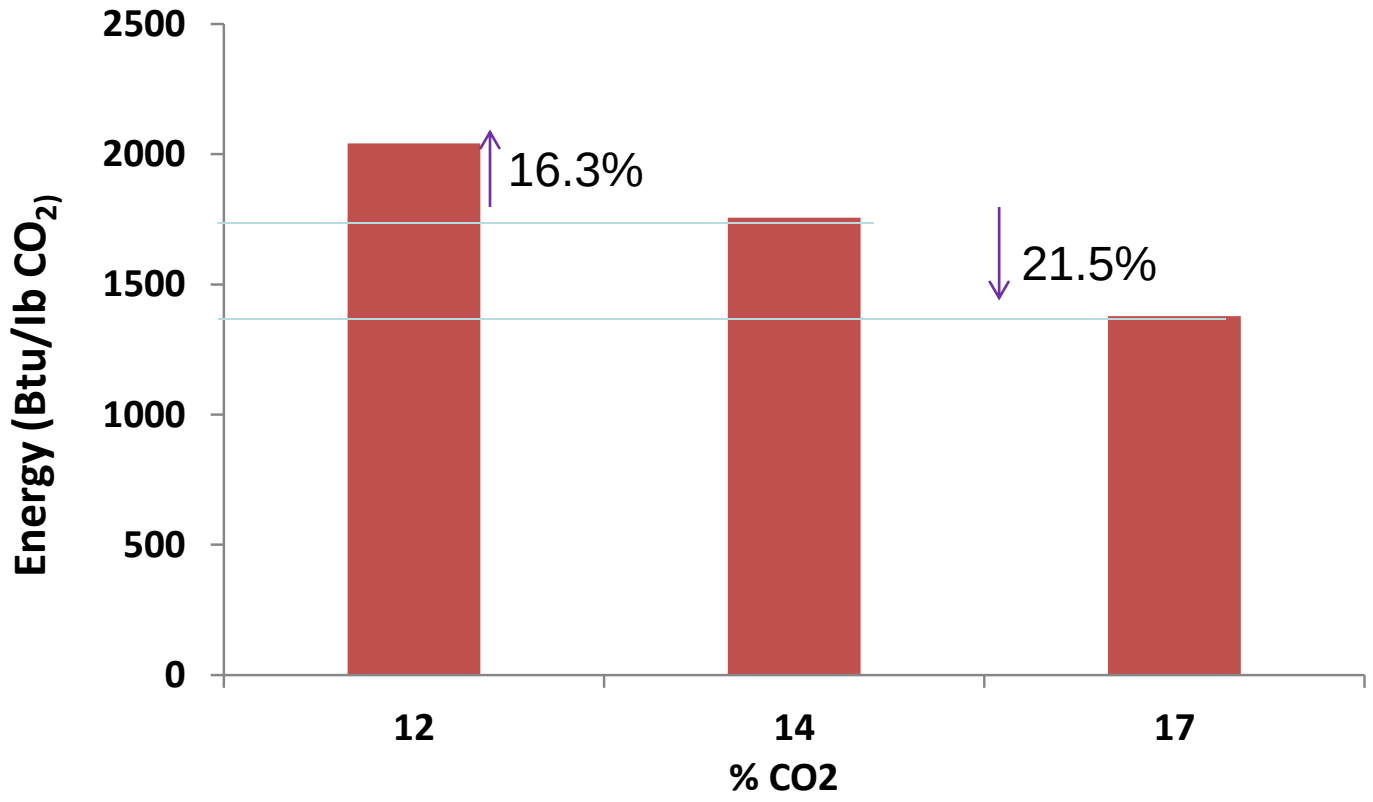
The Effect of CO_2 Concentration at Absorber Inlet on Energy Consumption



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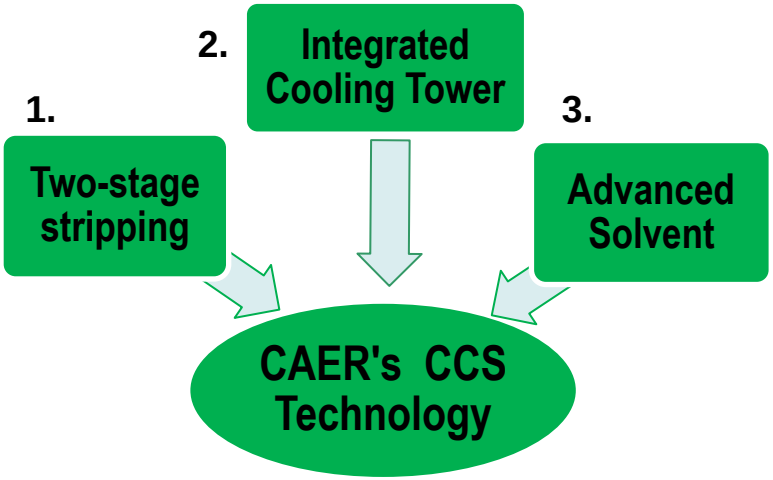
What We Have Proposed

Engineering design, build and install an advanced CO_2 capture system into an existing PC power plant at a 0.7 MWe slipstream scale (~15 TPD CO_2)

Three novel processes will be designed and integrated: 2-stage solvent striping, cooling tower desiccant, and Hitachi solvent



1. **Two-stage Stripping:**
   - Increase solvent working capacity by providing a secondary air-stripping column following the conventional steam stripping column.
   - Air stripping stream sent to boiler as combustion air to increase flue gas P_{CO_2} exiting boiler

2. **Integrated Cooling Tower:**
   - Use regenerated CO_2 stream waste heat to dry liquid desiccant
   - Liquid desiccant is used to dry cooling tower air → Improved power plant cooling tower and steam turbine efficiency

3. **Advanced Hitachi Solvent:**
   - Primary amine analogous to MEA

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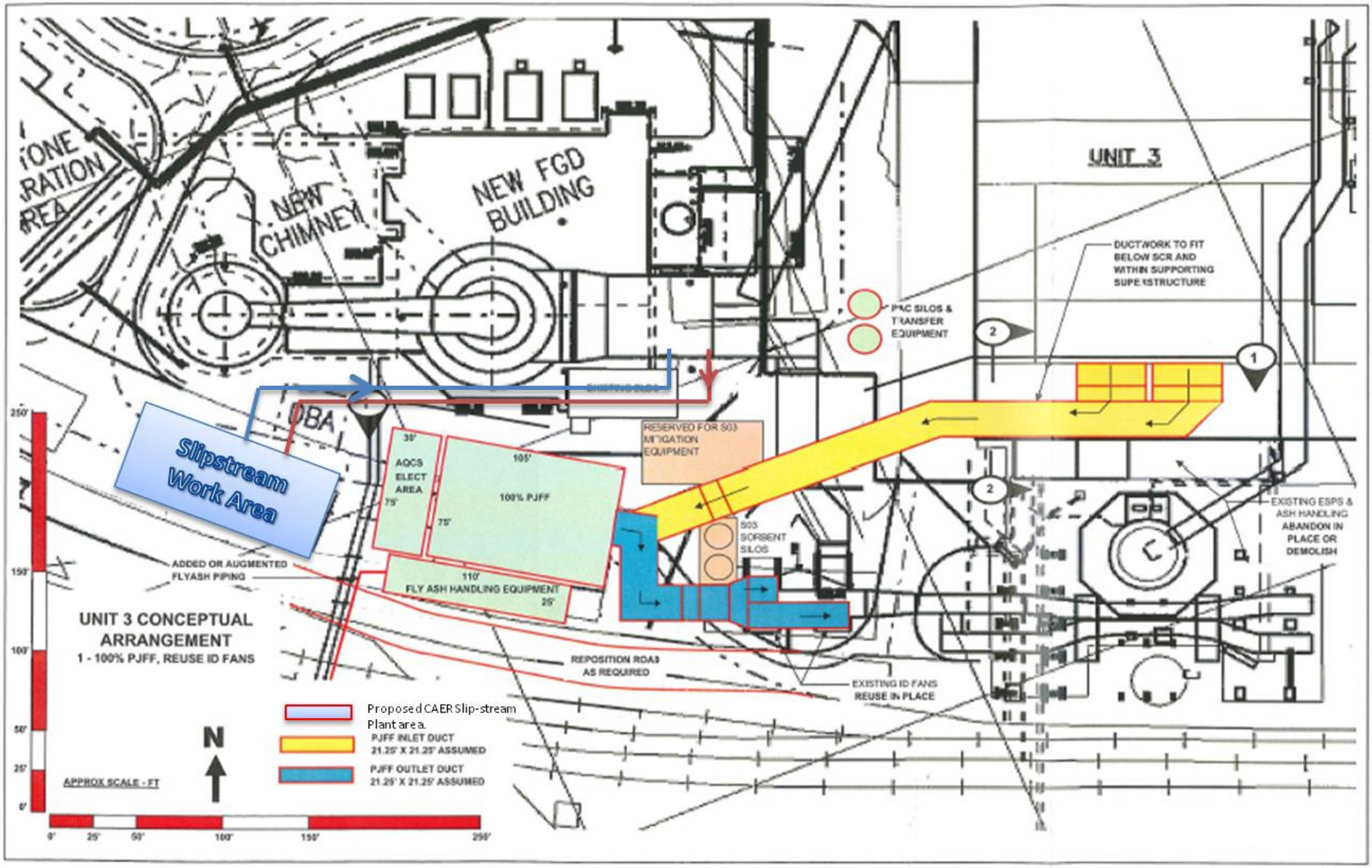
Testing Site: LG&E and KU's Brown Generating Station



Boilers Used for Testing

- Unit 1: B&W wall fired sub-critical boiler with Westinghouse 110 (gross) MW reheat turbine (1450 psig/1000°F/1000°F), ESP, and Low NOx burners;
- Unit 2: CE t-fired sub-critical boiler with Westinghouse 180 MW (gross) reheat turbine (1800 psig /1000°F /1000°F), ESP, Low NOx burners, and OFA;
- Unit 3: CE t-fired sub-critical boiler with Westinghouse 457 MW (gross) reheat turbine (2400 psig/1000°F /1000°F), ESP, Low NOx burners, and OFA.
- FGD common to all 3 units, in near future, SCR and SAM Mitigation Equipment

BPs and Tasks (still under discussion)

BP	Task	Name
	1.0, 5.0, 9.0, 17.0	**Project Management & Planning**
1	2.0	**System and Economic Analysis.**
	3.0	**Initial EH&S Assessment**
	4.0	**Basic Process Specification and Design**
2	6.0	**Slipstream Site Suvery**
	7.0	**Finalized Engineering Specification and Design**
	8.0	**Test Condition Selection and Test Plan**
3	10.0	**System Engineering Update and Model Refinements**
	11.0	**Update of EH&S Assessment**
	12.0	**Site Preparation**
	13.0	**Fabrication of Slip-stream Modules**
	14.0	**Procurement and Installation of Control Room/Field**
	15.0	**Fabrication of Corrosion Coupons**
	16.0	**Slipstream Facility Erection, Start-up, Commissioning**
4	18.0	**Slip-stream Test Campaign**
	19.0	**Final Updater of Techno-Economic Analysis**
	20.0	**Final EH&S Assessment**

Test Variables

Factors	Description	Level 1 (-1)	Level 2 (0)	Level 3 (1)
A	L/G Ratio (wt/wt)	0.2	0.5	0.8
B	Stripper Pressure (bar)	1.3	3	4.5
C	Inlet CO_2 Concentration (vol %)	10	12	14
D	Solvent Blow-down (%)	0.5	1	2

Sampling and Instrumentation

Instrumentation	Items Determined	Samples
On-line Gas and Liquid Analyzers	Gaseous composition Carbon loading	Gas and Liquid
HPLC-MS and GC-MS	Solvent and degradation products	Gas and liquid
IC	Halogen, sulfur-, nitro-compounds	Gas and liquid
ICP	Trace metals	Liquid
Titrator / phosphoric acid method	Alkalinity and total solution carbon	Liquid
pH, density meter	Solution pH, density	Liquid
Capillary viscometer and rise tensiometer	Solution viscosity and surface tension	Liquid
XRD	Coating and corrosion product	Metal coupon

Design Considerations

The Performance of Solvent Used in this Project		
Solvent	**Design Solvent (30 wt% MEA)**	**Performance Solvent (Hitachi H3-1)**
Net Cycle Capacity (mole/kg Solu)	1	1.25
Heat Required for Regeneration (Btu/lb-CO_2)	1380	1035
Mass Transfer flux in CO_2 absorper (relative to MEA)	baseline	1.2x
Heat Capacity relative to MEA	baseline	1.0x
Viscosity relative to MEA	baseline	1.0x
Surface Tension relative to MEA	baseline	1.0x
Foaming Tendency relative to MEA	baseline	less

- Design pressure for stripper and associated components: 150 psi
- Turn-down operation will be 4:1 ratio
- Structure support: (middle suspension??)

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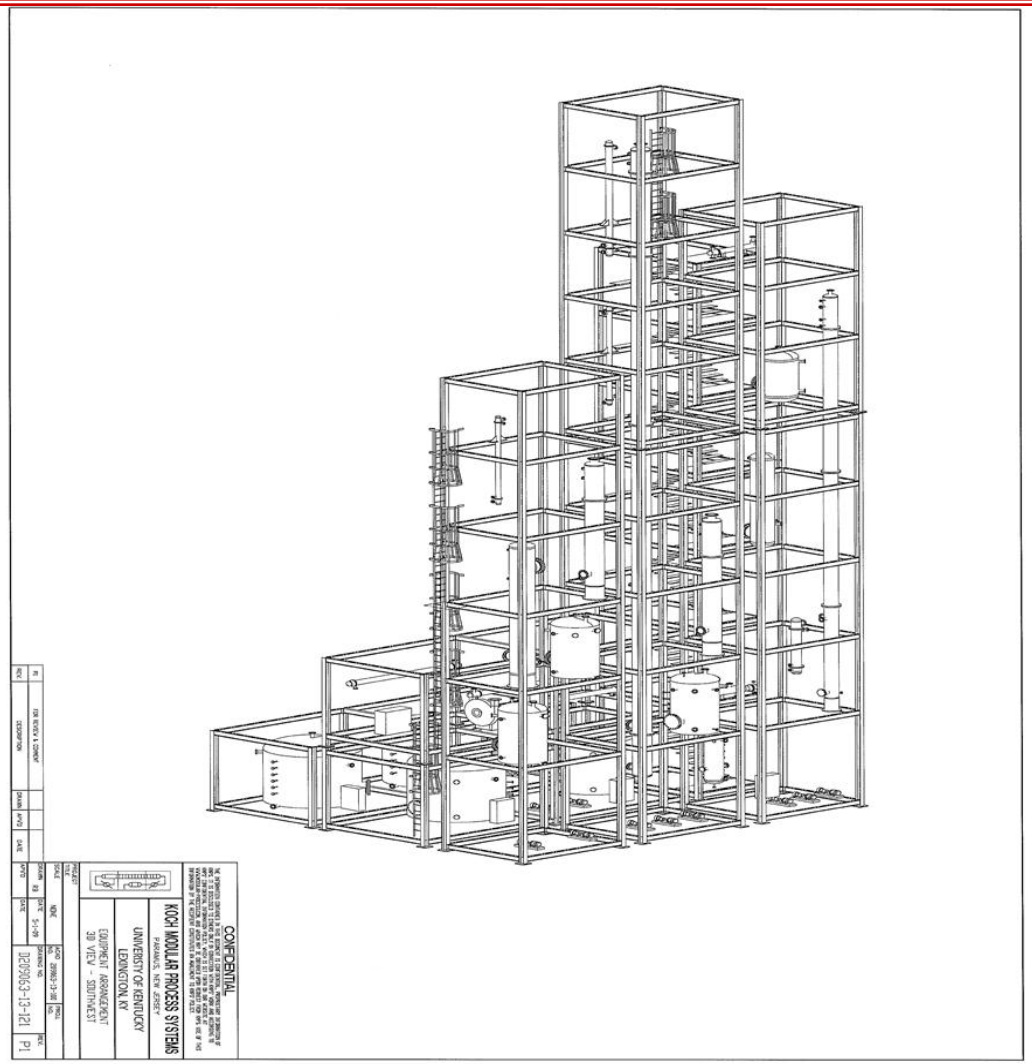
Preliminary 3-D View of Slipstream Unit



- 80 ft tall
- 1000 ft^2 footprint (15'x65', but could be rearranged)
- 5 to 6 modulus with 100,000lbs/modulus
- Plus control/lab trailer and others

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Output

- An advanced heat-integrated post-combustion CO_2 capture process that could be applied to various solvents;
- Knowledge on water balance and solvent management, and metal corrosion as well;
- Gain experience on system dynamics corresponding to load, trip and upset;
- Data on gas/liquid emission and solvent degradation

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