Evaluation of Concentrated Piperazine for CO_2 Capture from Coal-Fired Flue Gas

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URS Corporation

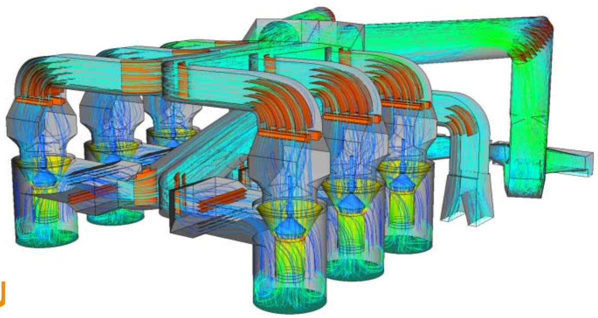
DOE-NETL Contractor's Meeting
September 15, 2010

TRIMERIC CORPORATION

The University of Texas at Austin

URS Corporation

- *Leading Engineering and Construction Services Firms*
- *Approximately 42,000 employees in 30+ countries*
- *Annual revenues - $10B*
- *Process Technologies Office - Austin, TX*
  - *Air pollution controls (SO_2, SO_3, Hg, Se, CO_2)*
  - *Water/wastewater management*
  - *Lab scale R&D, pilot plant and demonstration scale projects*
    - *32,000 ft^2 laboratory facility*



Project Participants

- Team Members
  - **URS** (PjM: Katherine Dombrowski)
  - **University of Texas at Austin** (PI: Gary Rochelle)
  - **Trimeric** (PjM: Kevin Fisher)
- Host Sites
  - **CSIRO**'s Post Combustion Capture facility at Tarong
  - **UT**'s Separations Research Plant
  - **DOE**'s National Carbon Capture Center
- Cost-Share Providers
  - CO_2 Capture Pilot Plant Project at UT
    - Funded by EPRI, Luminant, E.on, Southern Company

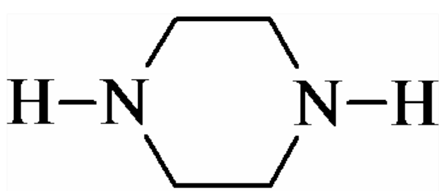
Funding

- Q1 GFY 2011 – Q4 GFY 2013
- DOE: $3,000,000
  - DOE-NETL Project Manager: Bruce Lani
- Cost Share: $866,711
  - University of Texas at Austin: CO_2 Capture Pilot Plant Project (C2P3)
    - Cash designated by EPRI and utility members to this DOE-NETL project to provide modifications to the 0.1 MW skid

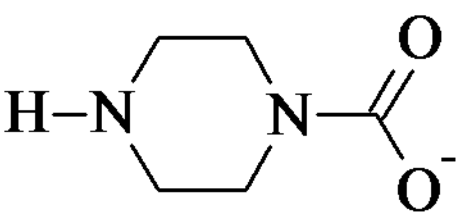
CO_2 Absorption by Piperazine

- **Absorption** of CO_2 with concentrated (8m, 40 wt%) piperazine
- **Regeneration** with high-temperature 2-stage flash

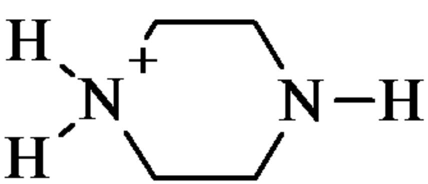
Piperazine (PZ)



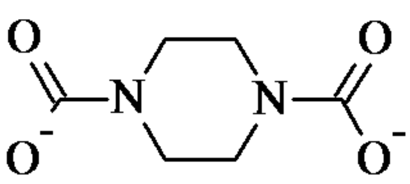
PZ Carbamate



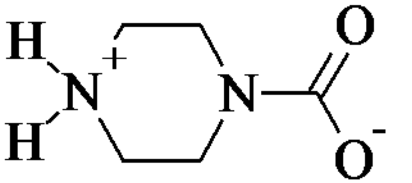
Protonated PZ



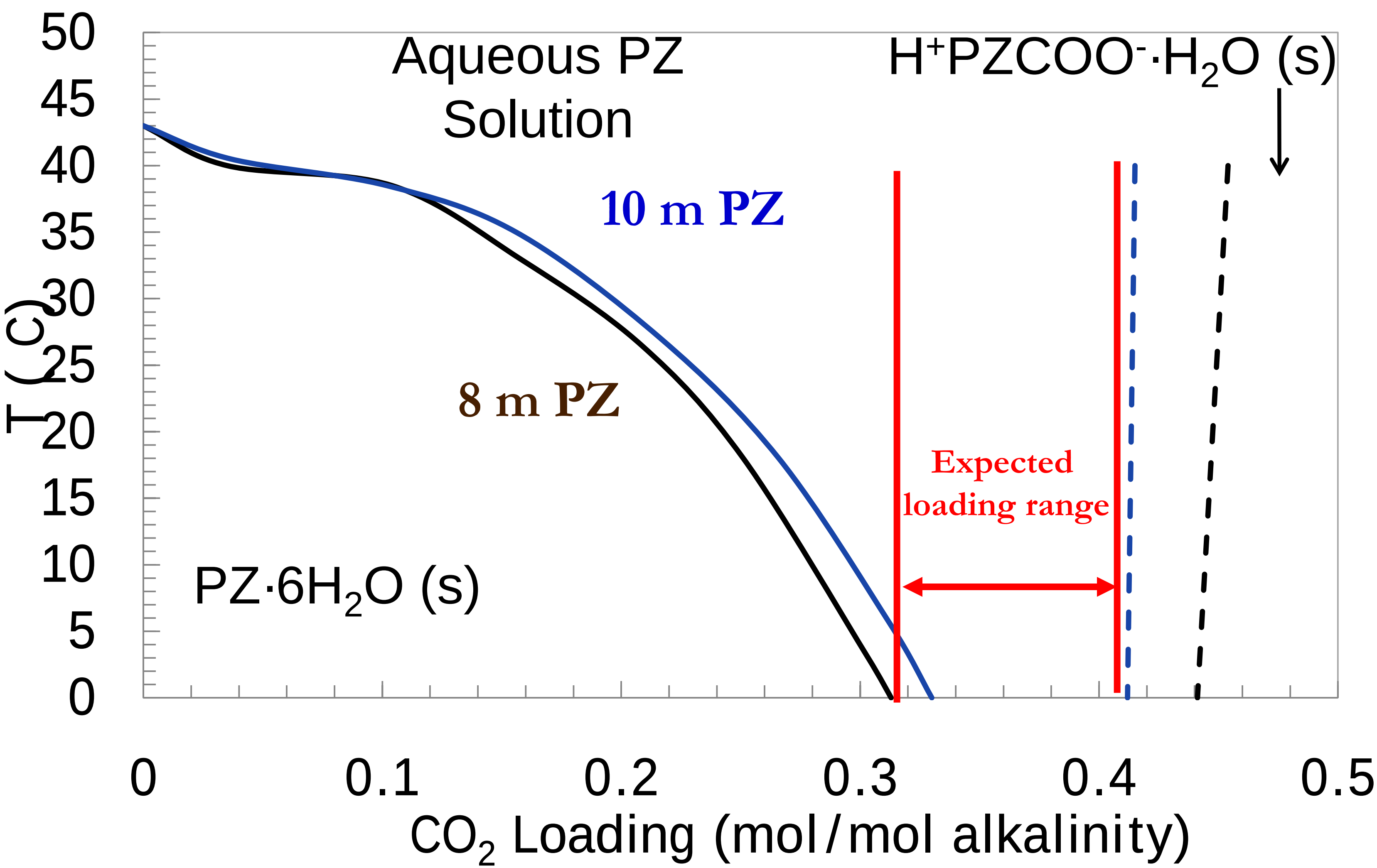
PZ Dicarbamate



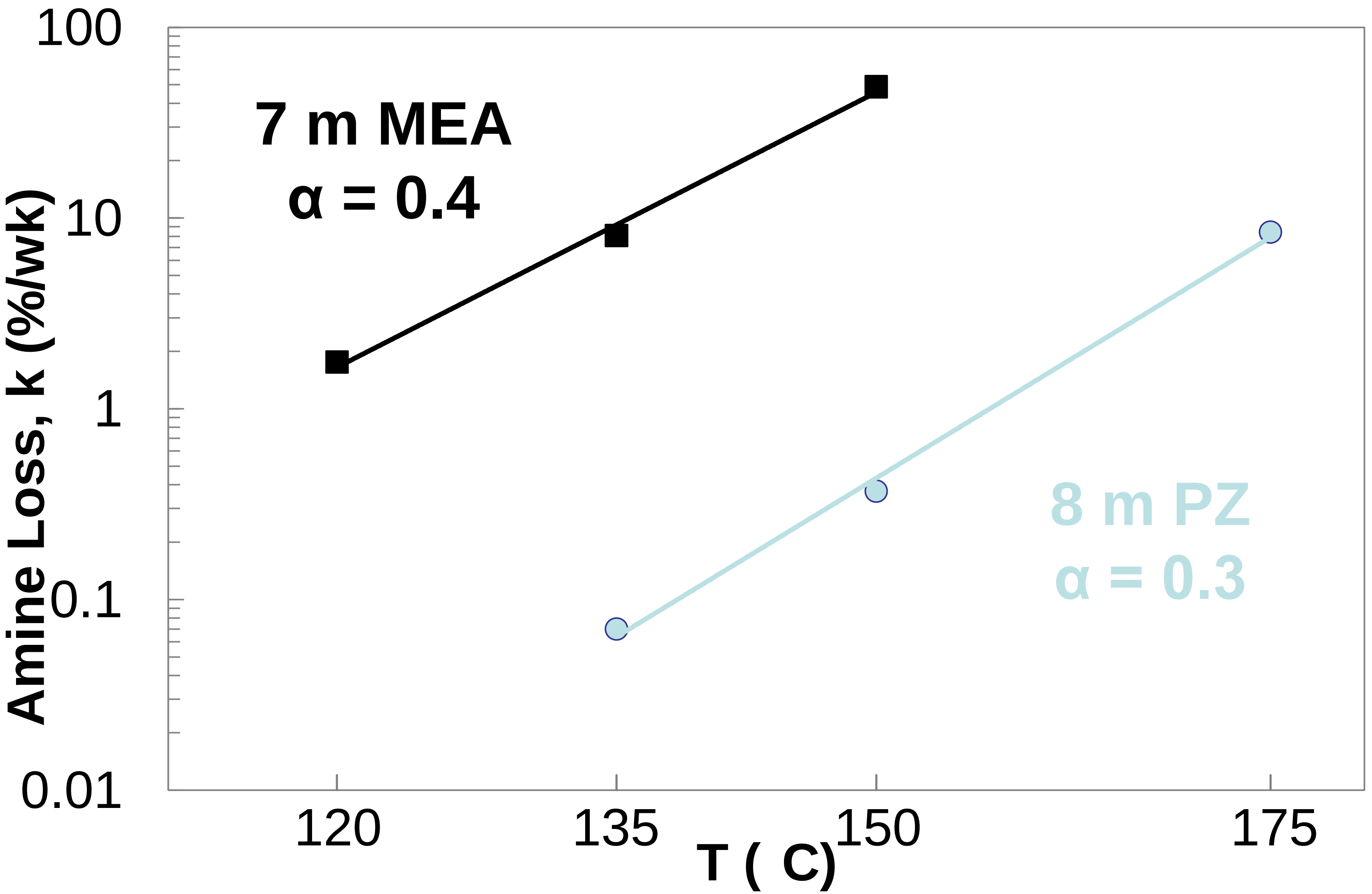
Protonated PZ Carbamate



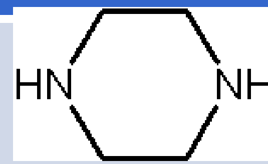
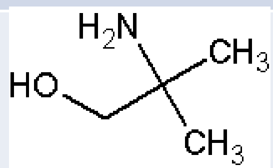
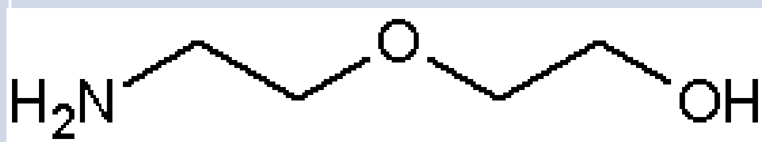
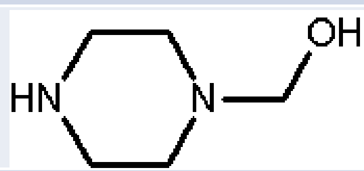
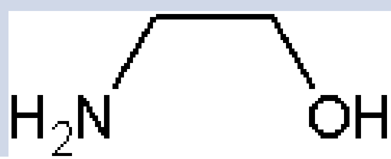
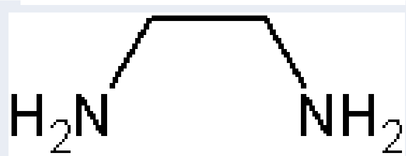
Solubility Envelope for PZ Permits Concentrated Solvent



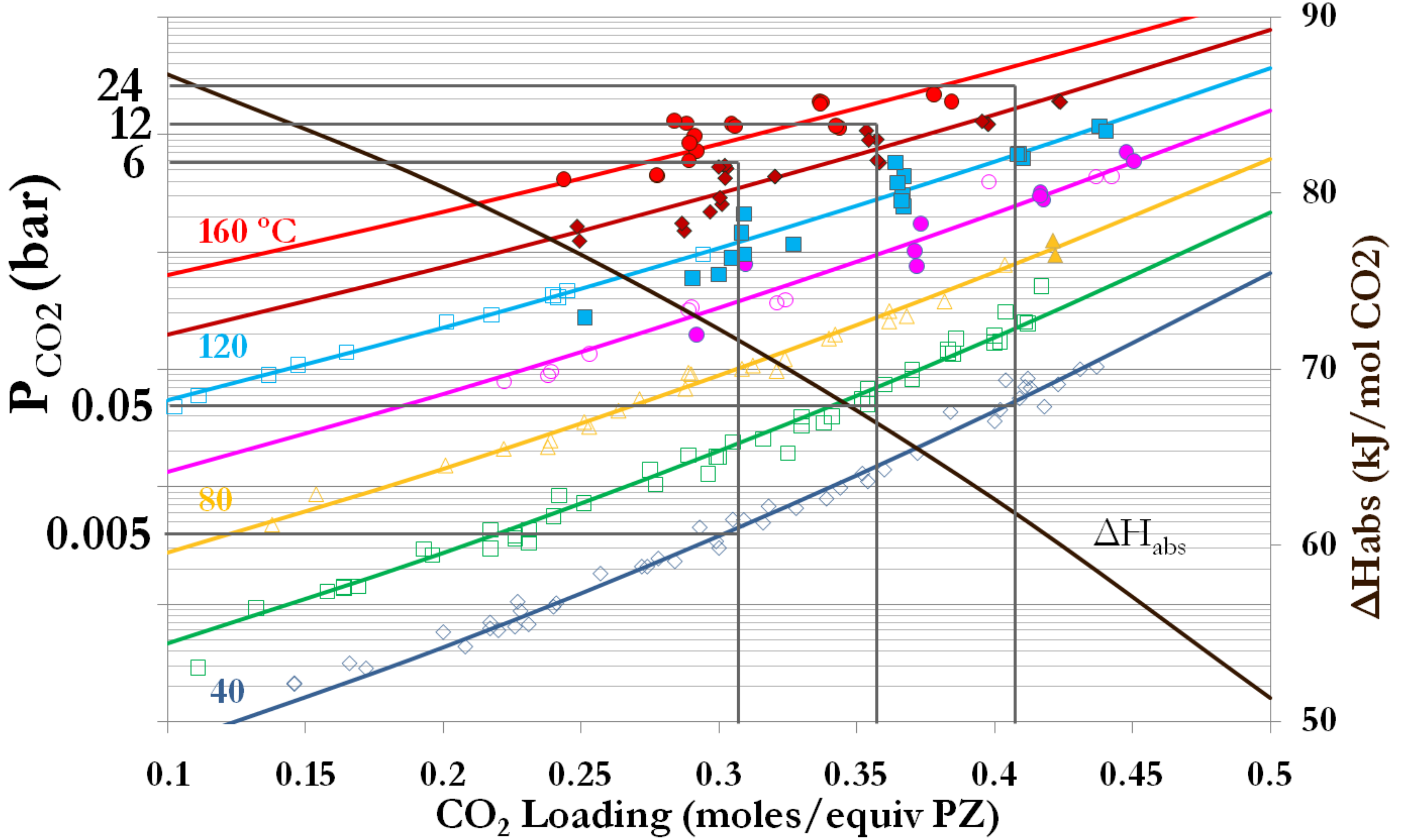
Thermal Stability Permits 150 C Stripping



Thermal Degradation at 135 C

Amine	Structure	k (%/wk)
PZ		0.07
AMP		1.2
DGA		2.1
HEP		2.8
MEA		8.1
EDA		10.1

8m PZ Provides High P at 150 C



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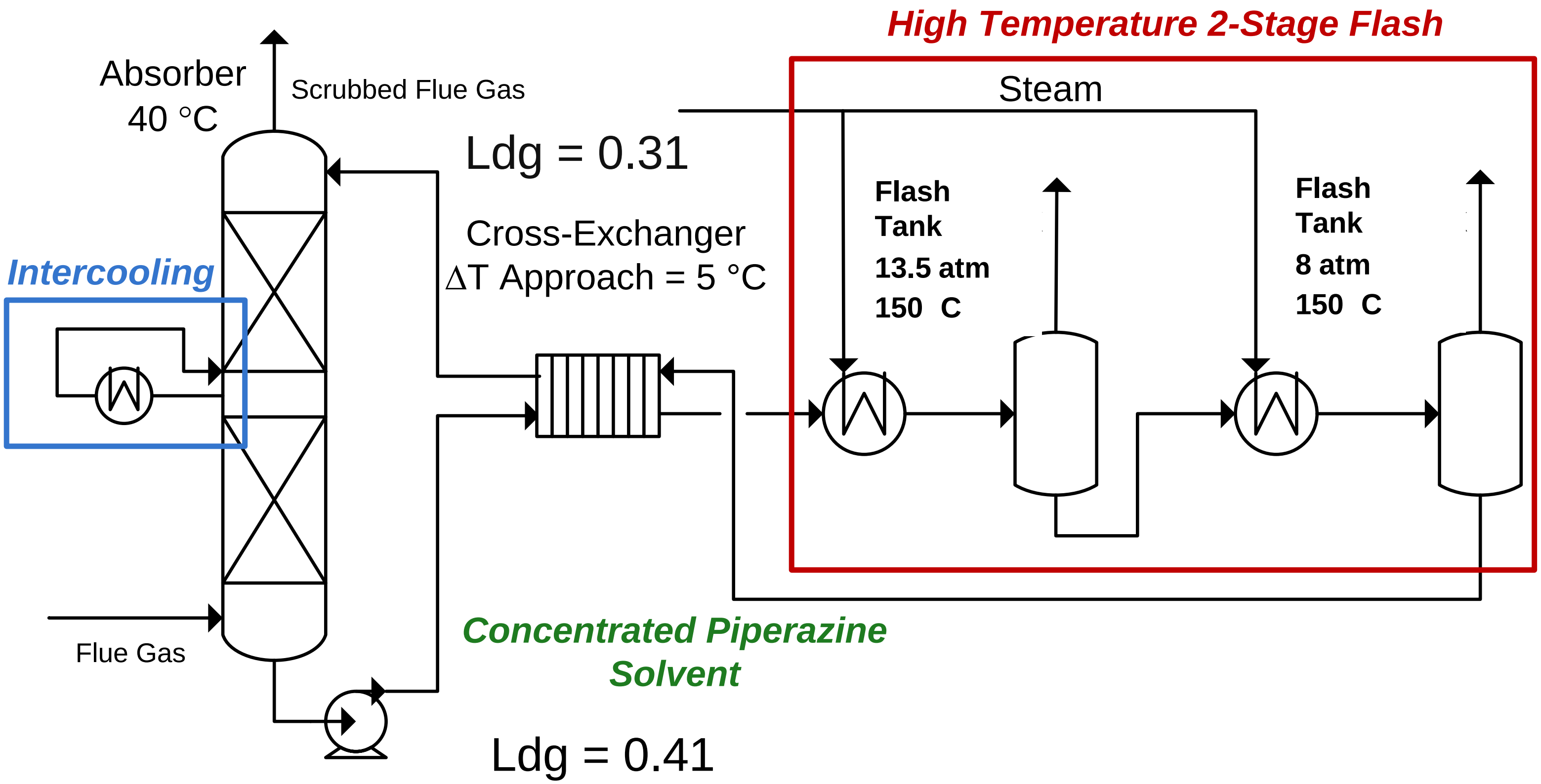
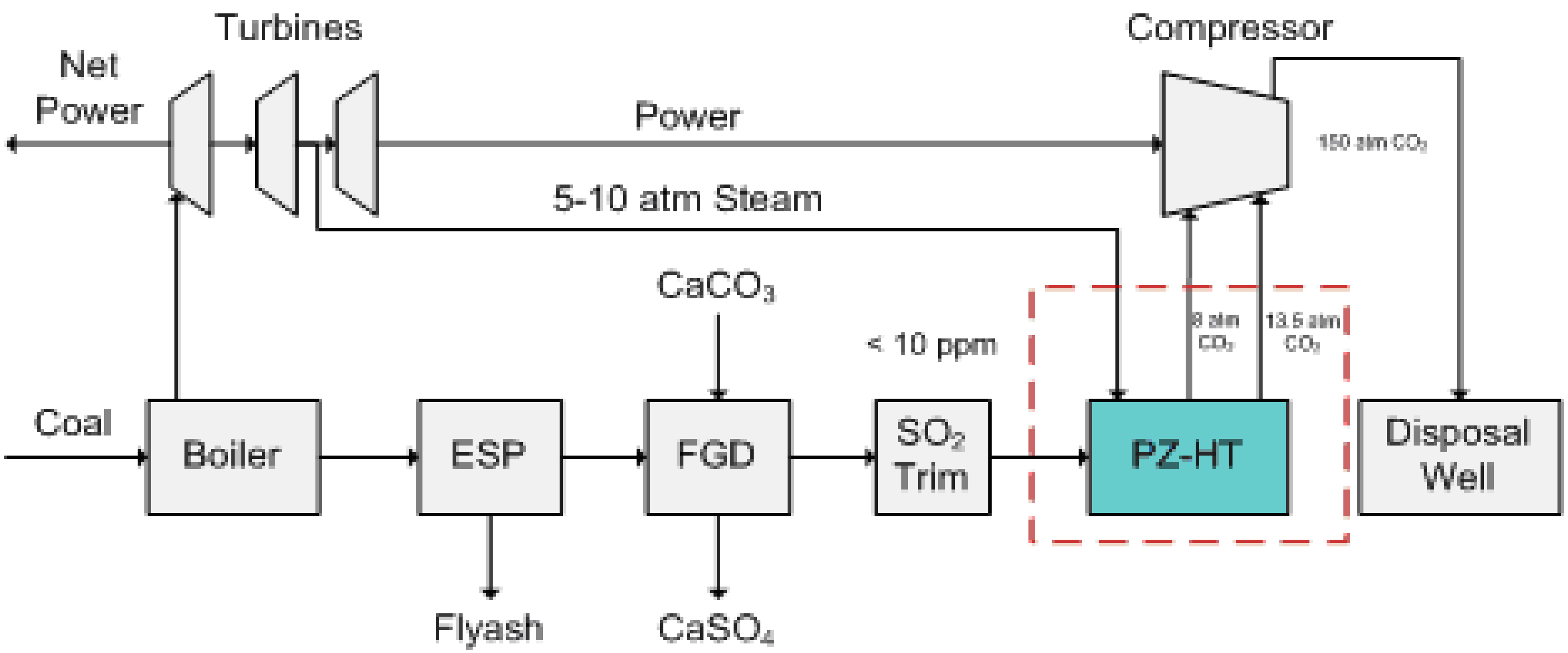
Advantages of Piperazine

	7 m MEA	8 m PZ
CO_2 Abs Rate (mol/s-Pa-m-^{2})	4.3x10^7	2X
Working Capacity (mol/eq)	0.48	1.8X
Volatility – Lean (ppm)	30	7
Thermal Stability (C)	120	150
Oxidative Degradation	18%/wk	Neglig.
Reclaiming – Boil Pt (C)	170	146
Energy Use (kWh/tonne)	250	10-20% <

Process Flow Diagram



Integration of PZ-HT into Power Plant



Production of CO_2 at elevated pressure, lowering compression costs

Economic Advantages

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From DOE/NETL-2007/1281

	% CO_2 Capture	Energy (MWh/ton CO_2 removed)	CapEx ($/net kwh)	COE (¢/kwh)
No capture	0%	0	1549	6.4
30% MEA	87%	0.38	2895	11.9
PZ-HT	90%	0.23	2330	9.4

- **Additional savings in COE may be achieved by**
  - Optimization of absorber packing
  - Flue gas pre-treating
  - Compressors
  - Heat exchangers
  - Design improvements realized as part of this project

Challenges

- Robustness of concentrated PZ in flue gas must be demonstrated
  - PZ more expensive to replace than MEA
- Robustness of process to excursions in CO_2 loading, temperature and water balance must be demonstrated
  - Quantify effect on solids precipitation
  - Quantify effect on plant operation

Project Objectives

- Demonstrate robustness of PZ in integrated absorption/HT-stripping system
- Optimize equipment design and energy performance of PZ-HT
- Identify and resolve operational and design issues, including process control, foaming, solids precipitation
- Evaluate technical and economic feasibility of full-scale implementation of the process

Work Plan

- Field Campaign #1: CSIRO 0.1 MW
  - 3-month test
  - Low-sulfur bituminous coal with caustic scrubber
  - First test in coal-fired flue gas
- Field Campaign #2: UT SRP 0.1 MW
  - 3-week test in CO_2/air
  - Test modifications of 2-stage flash prior to 0.5 MW design
- Field Campaign #3: NCCC 0.5 MW
  - 3-month test
  - Medium-sulfur bituminous coal with limestone scrubber

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Schedule

- 36 month project
- Tests with 0.1 MW Regeneration Skid
  - CSIRO Test: March – May 2011
  - SRP Test: November – December 2011
- Design/Build 0.5 MW Regeneration Skid: 2012
- Test with 0.5 MW Regeneration Skid
  - NCCC Test: February – April 2013

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New solvent/process development areas for project

- 40 wt% PZ solvent with fast CO_2 absorption rates, high capacity, and thermal stability
- Integrated process with absorber intercooling and solvent regeneration by a high temperature two-stage flash with concentrated PZ
- Quantification of thermal and oxidative degradation of concentrated PZ with coal-fired flue gas with a cyclic absorber/high temperature flash
- Scale-up from 0.1 to 0.5 MW of the optimized high temperature two-stage flash process and PZ solvent with coal-fired flue gas.

Plans for Future Development

- Pending successful testing of PZ-HT process at 0.1 MW and 0.5 MW, future steps include
  - Deployment of lessons learned in this project to future tests
  - Larger scale demonstrations, eventually leading to integration with power plant steam cycle
  - Longer-term demonstrations on a variety of coal types