

Solvent and Process Enhancements for CO₂ Absorption/Stripping

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Supported by

DOE Cooperative Agreement No. DE-FC26-02NT41440

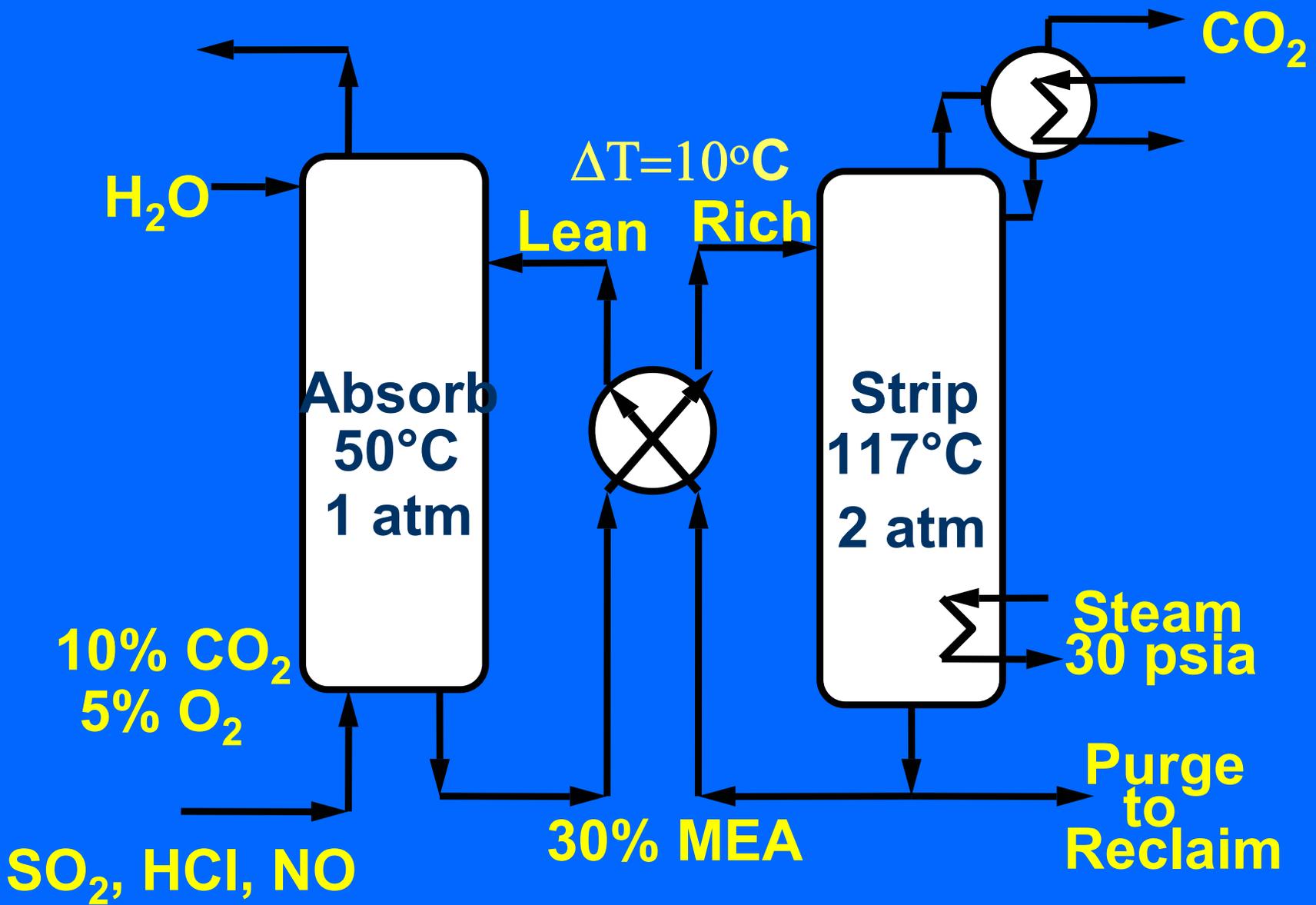
Industrial Associates Program for CO₂ Capture by Aqueous Absorption

This paper was prepared with the support of the U.S. Department of Energy, under Award No. DE-FC26-02NT41440, a number of industrial sponsors, an EPA Star Fellowship and the Separations Research Program at the University of Texas. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the DOE or other sponsors.

Outline

- Monoethanolamine (MEA) absorption/stripping
 - The “limestone slurry scrubbing” for CO₂ Capture
- Bench-scale Results with K⁺/Piperazine (PZ)
 - Heat of Absorption from 50 to 100% of MEA
 - 1 to 1.5 times faster than MEA
- Pilot Plant Results with 3 Packing types
 - Better packing = richer soln = reduced energy
- Modeling results w 4 solvents
 - Benefits of innovative stripper configurations
- Energy savings of 5 to 25%

MEA Absorption/Simple Stripping



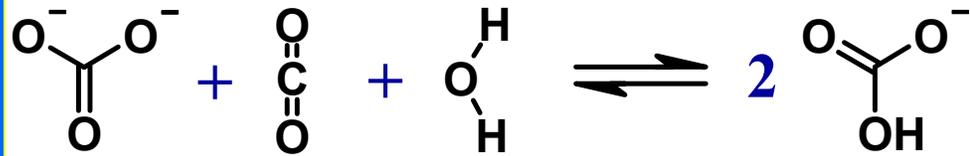
Aqueous Absorption/Stripping

- Analogous to CaCO_3 Slurry Scrubbing - 1975
 - The feasible technology for existing coal plants
 - Looks expensive, but we will use it anyway.
- Near commercial technology
 - Process used for treating H_2 & natural gas
 - MEA demonstrated on small coal plants
 - Promoted K_2CO_3 used for H_2 treating
- Tail End technology development
 - Low risk, low cost, and short time
 - Resolve problems in small pilot plants
 - Demo Full-scale absorbers with 100 MW gas

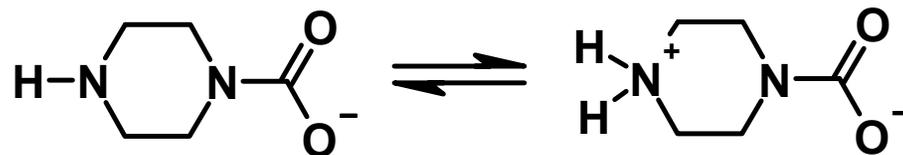
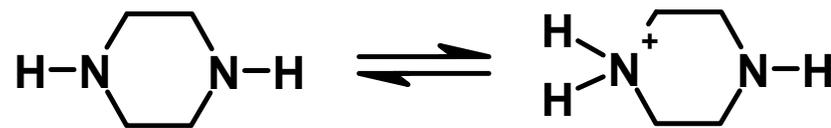
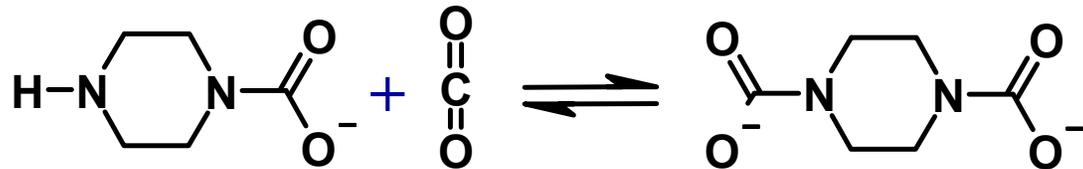
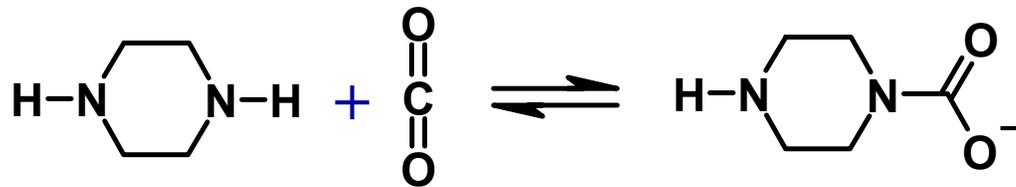
- Weaknesses in the state-of-the art
 - High Energy: 15 - 40% of power out
 - Slow Rates: 15 m packing = 25-50% approach
- Opportunities
 - Develop Better Solvent : K⁺/PZ
 - Heat of desorption = 50 -100% of MEA
 - CO₂ absorption rate = 1 – 1.5 times MEA
 - Utilize high surface area packing
 - Innovate new stripper configurations

CO₂ Absorption by K⁺/Piperazine

Carbonate Species

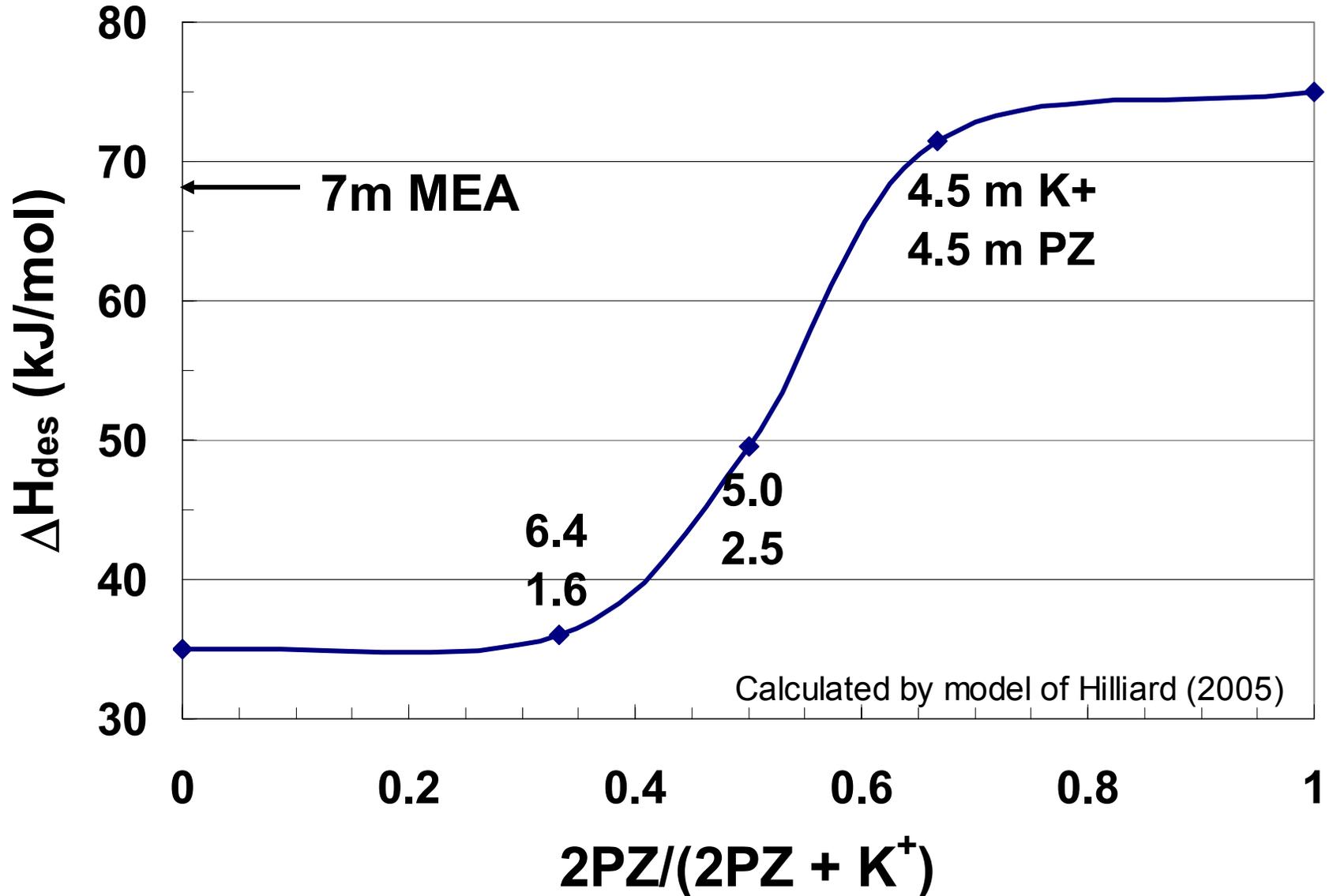


Piperazine Species

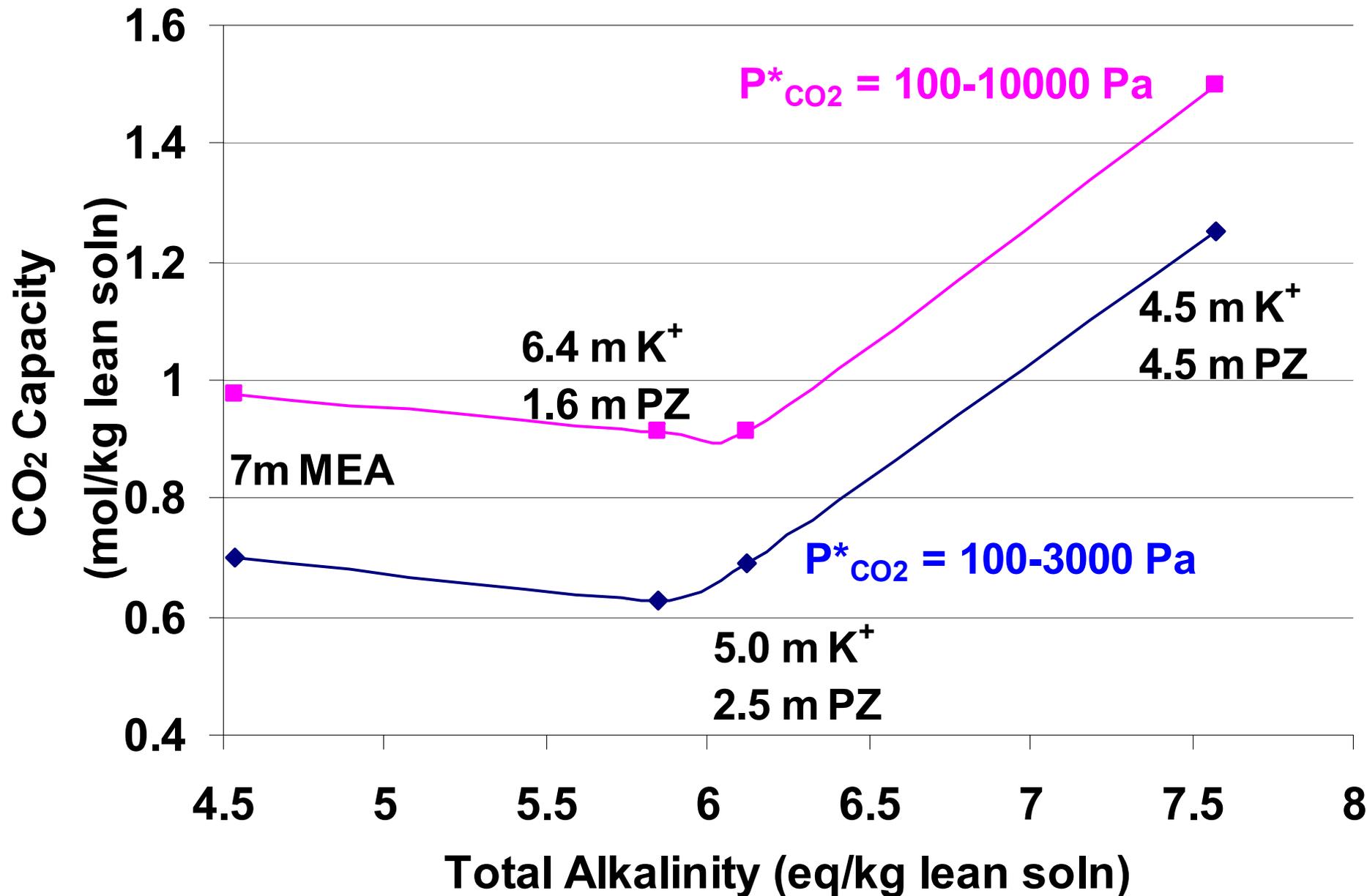


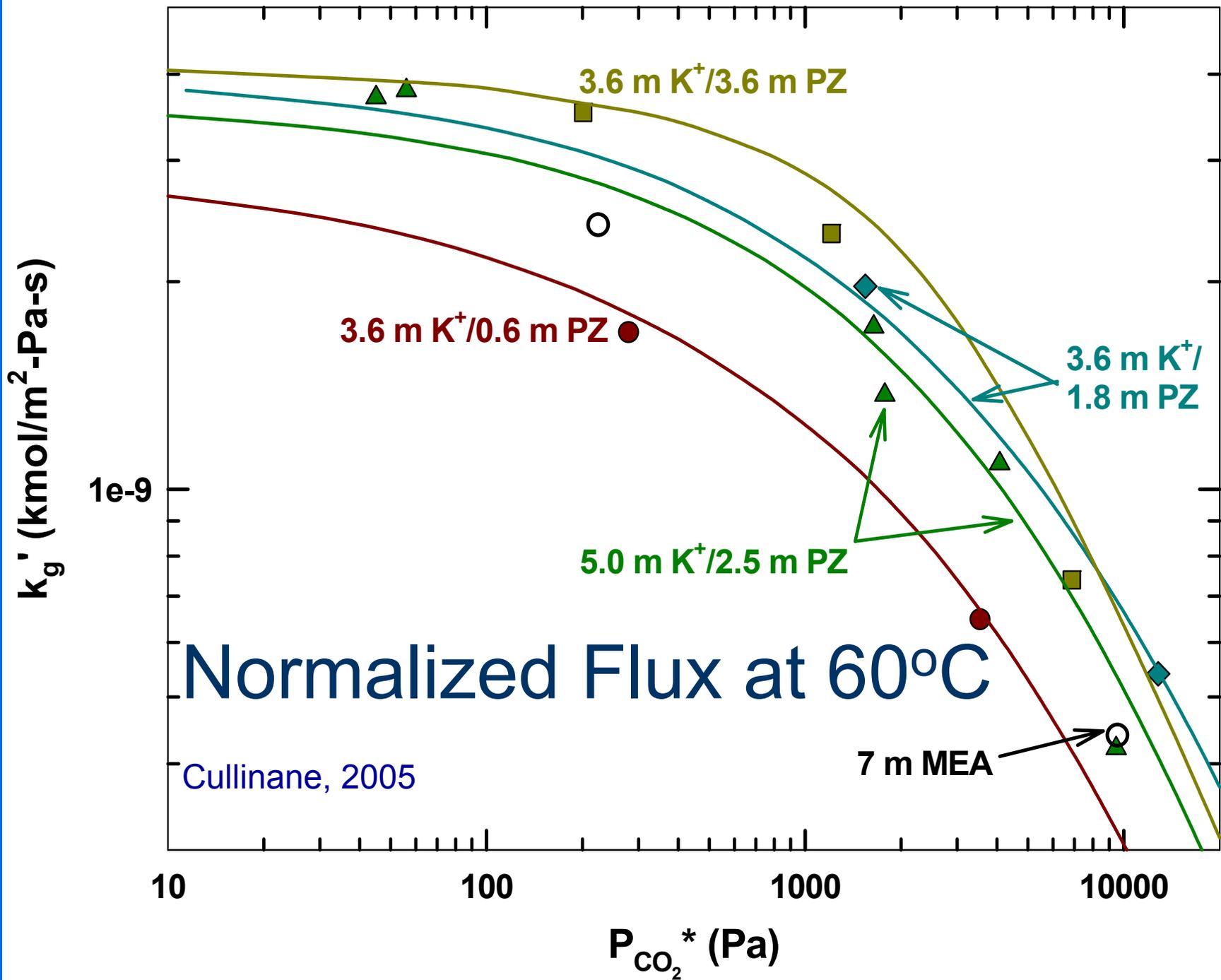
Heat of CO2 desorption

$$P^*_{\text{CO}_2} = 3000 \text{ Pa}$$

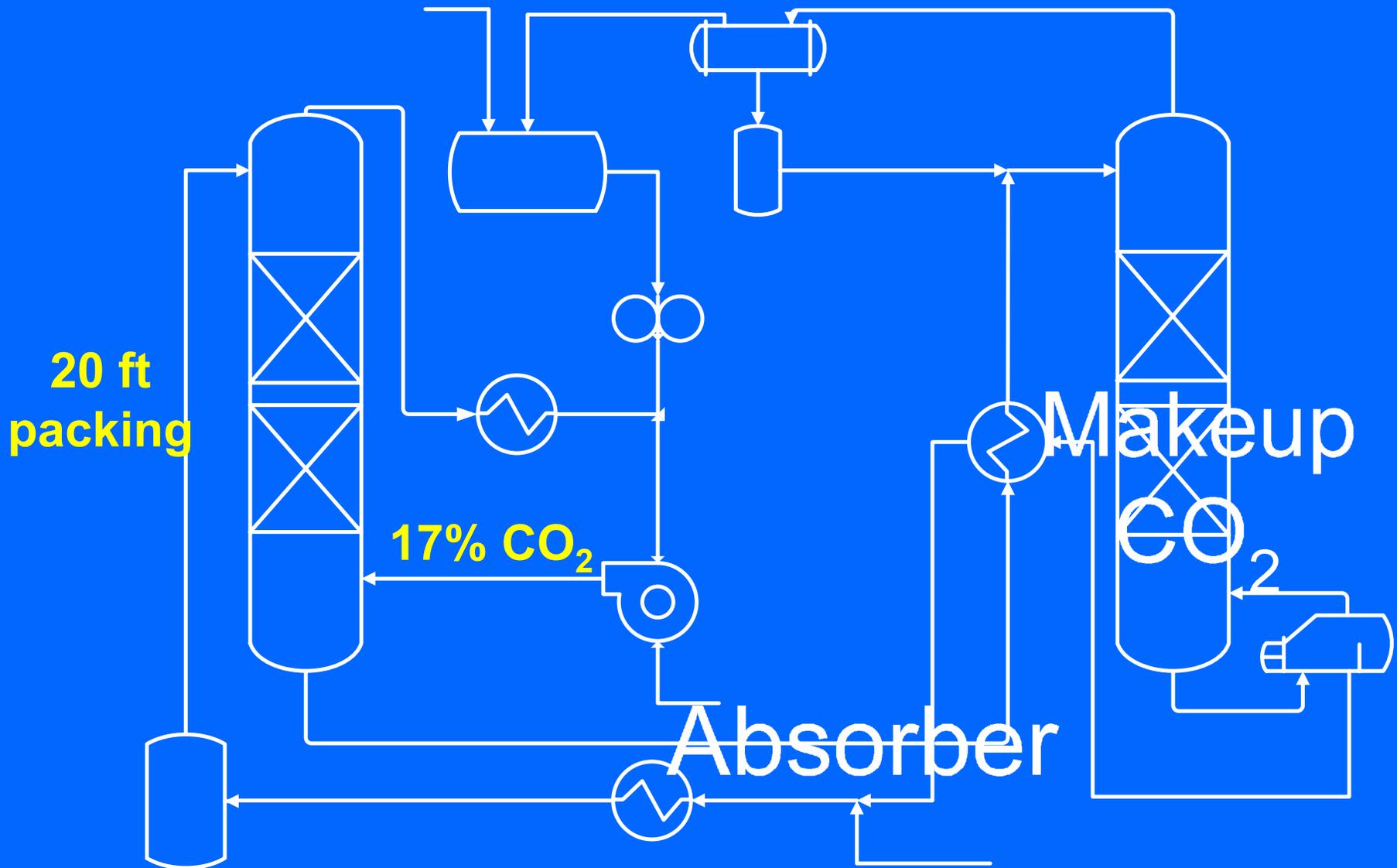


CO₂ Capacity at 40°C

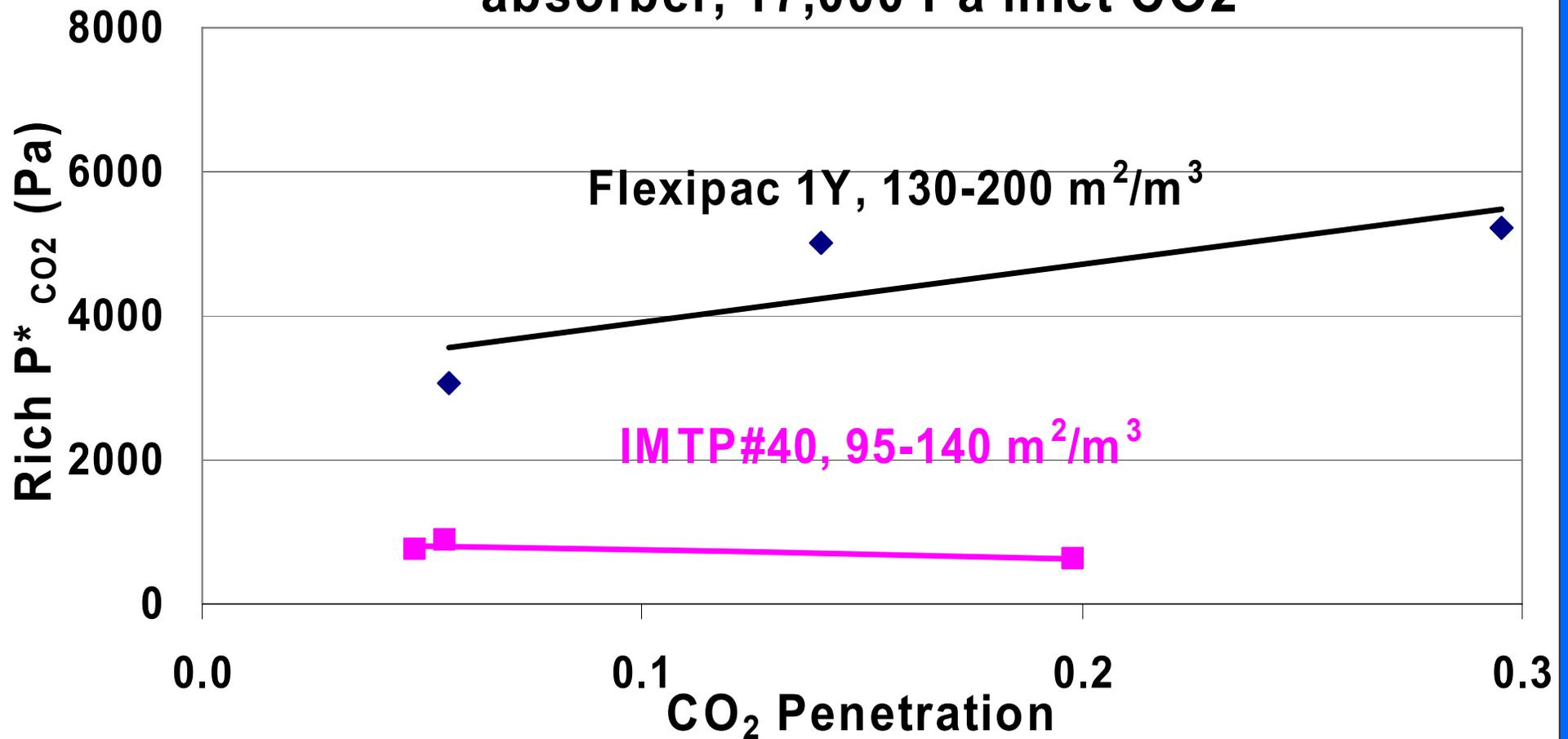




Pilot Plant with 16.8-inch contactors



**Pilot Plant Performance with 32.5 wt% MEA
0.28 lean loading, 195 ACFM in 16.8-inch ID
absorber, 17,000 Pa inlet CO₂**



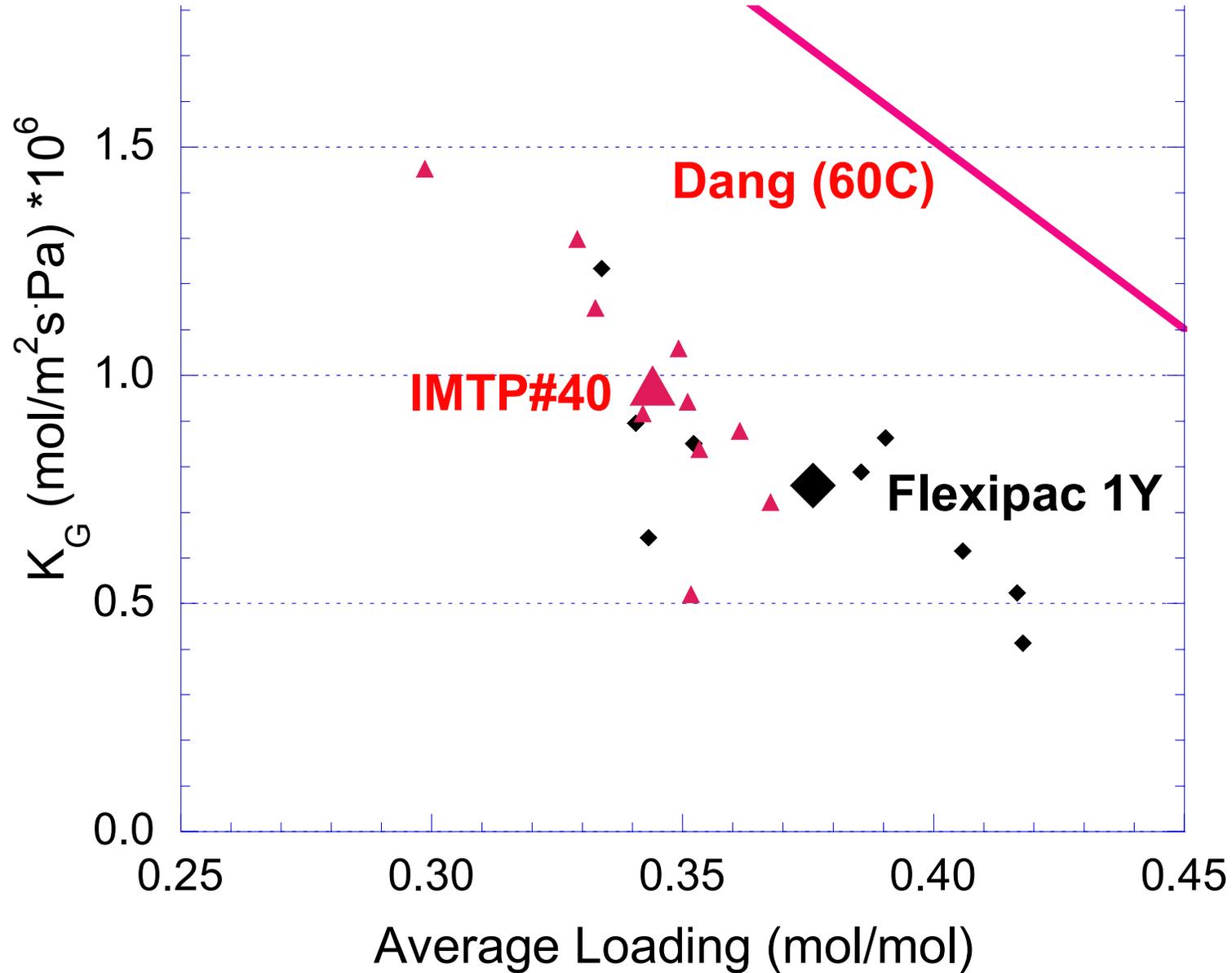
Absorber Mass Transfer

$$K_G = \frac{CO_2 \text{ Absorbed}}{\Delta P_{CO_2,lm} \cdot Volume_{Packing}} \frac{1}{a_{eff}}$$

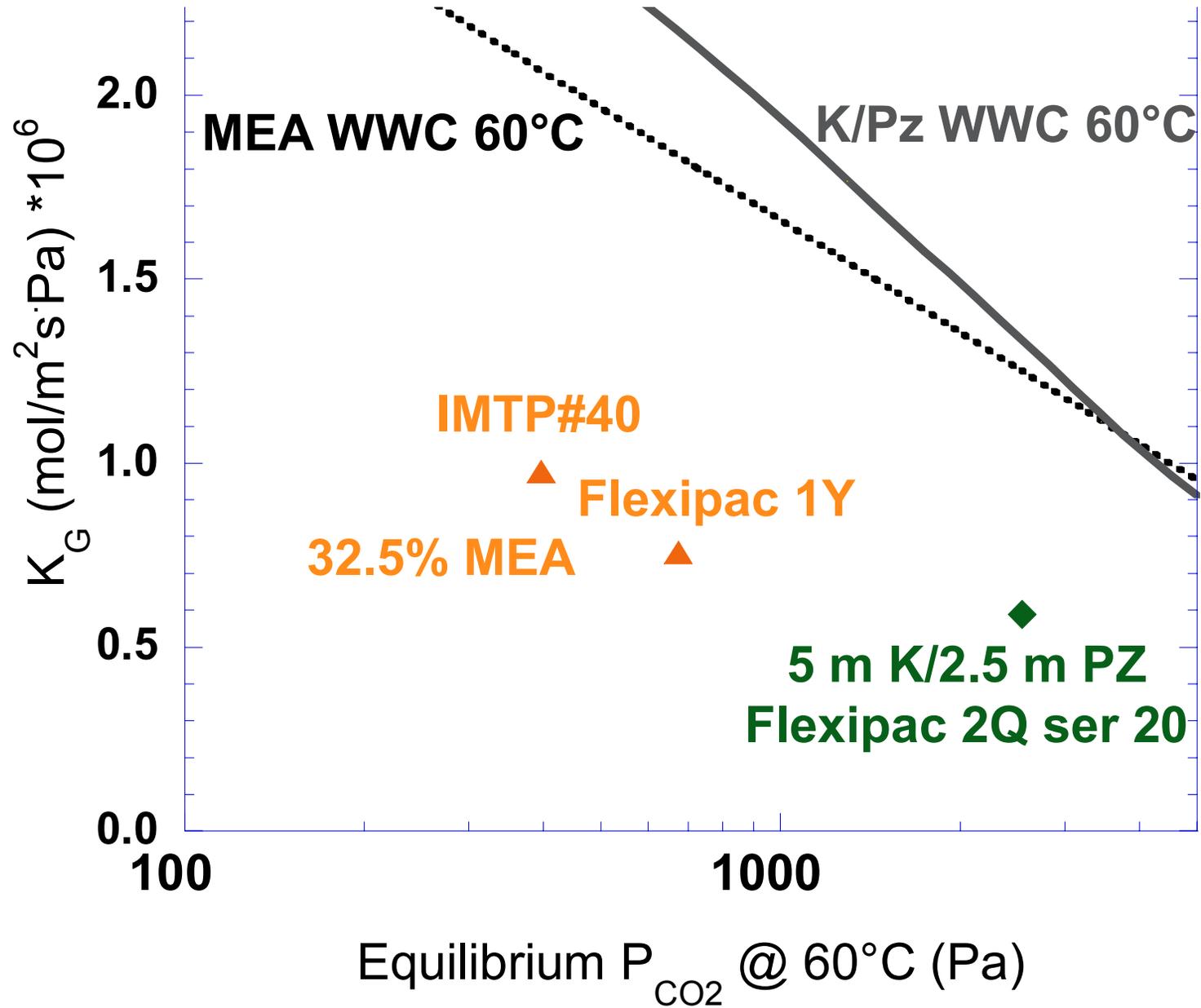
- Log mean P_{CO_2} driving force
 - Equilibrium from measured Idg and Aspen
- Measured Effective Area, a_{eff} (m^2/m^3)
 - CO_2 absorption from air
 - Into 0.1 M OH^-
 - Function of liquid and gas rates.

Pilot Plant Absorber Performance

32.5 wt% MEA, Corrected for Wetted Area



Bench-scale Rates compared to Pilot Plant Performance



Performance of Strippers

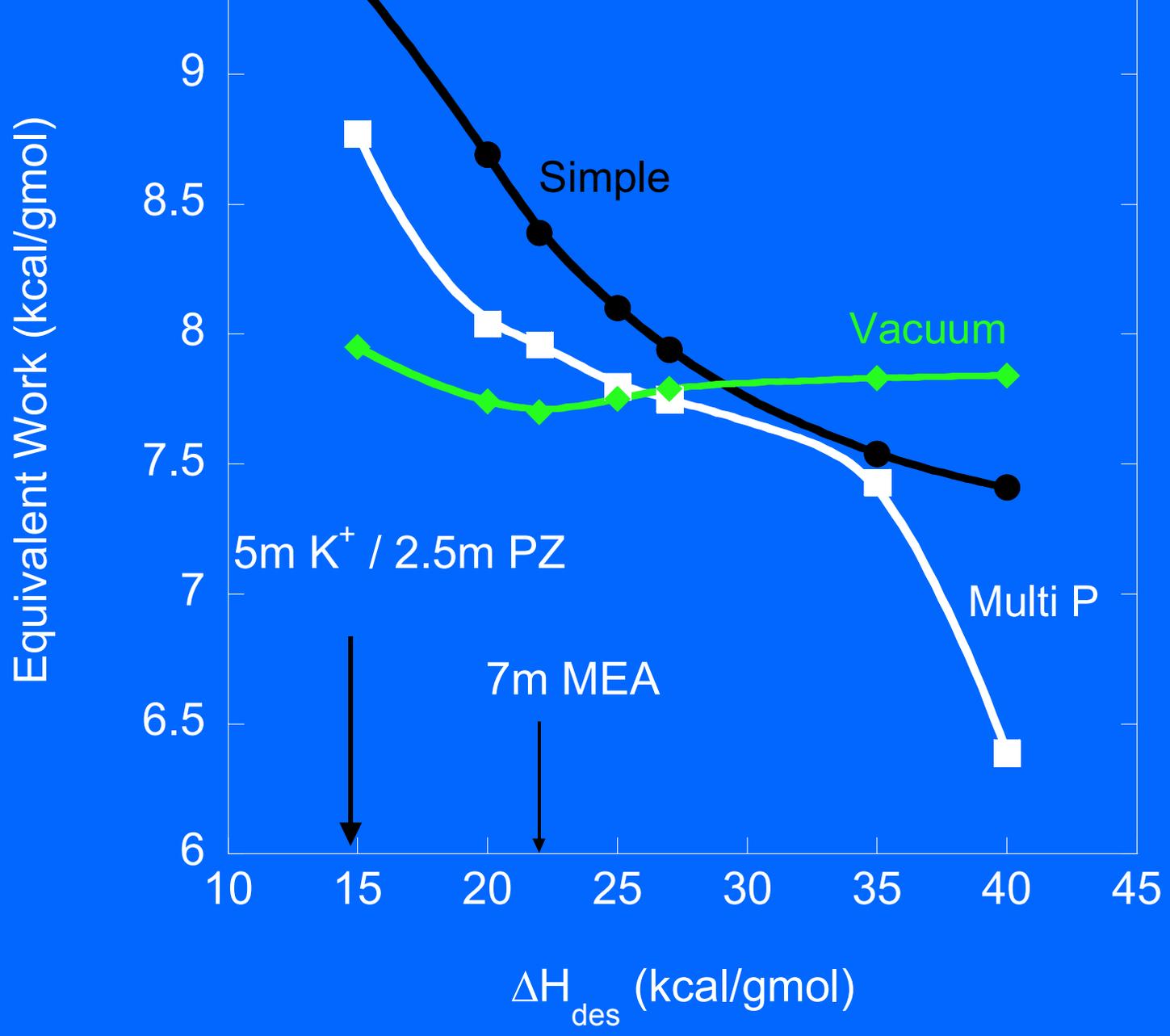
Concept of Equivalent Work (W_{eq})

$$W_{eq} = 0.75 Q_{reb} \left[\frac{T_{cond} - T_o}{T_{cond}} \right] + W_{comp}$$
$$= 0.75 Q_{reb} \left[\frac{(T_{reb} + 10) - 313}{(T_{reb} + 10)} \right] + W_{comp}$$

(75% Adiabatic Efficiency in Compressor)

Total Equivalent Work for Generic Solvents

(Rich $P_{CO_2}^* = 2.5$ kPa at $40^\circ C$, $\Delta T = 10^\circ C$)



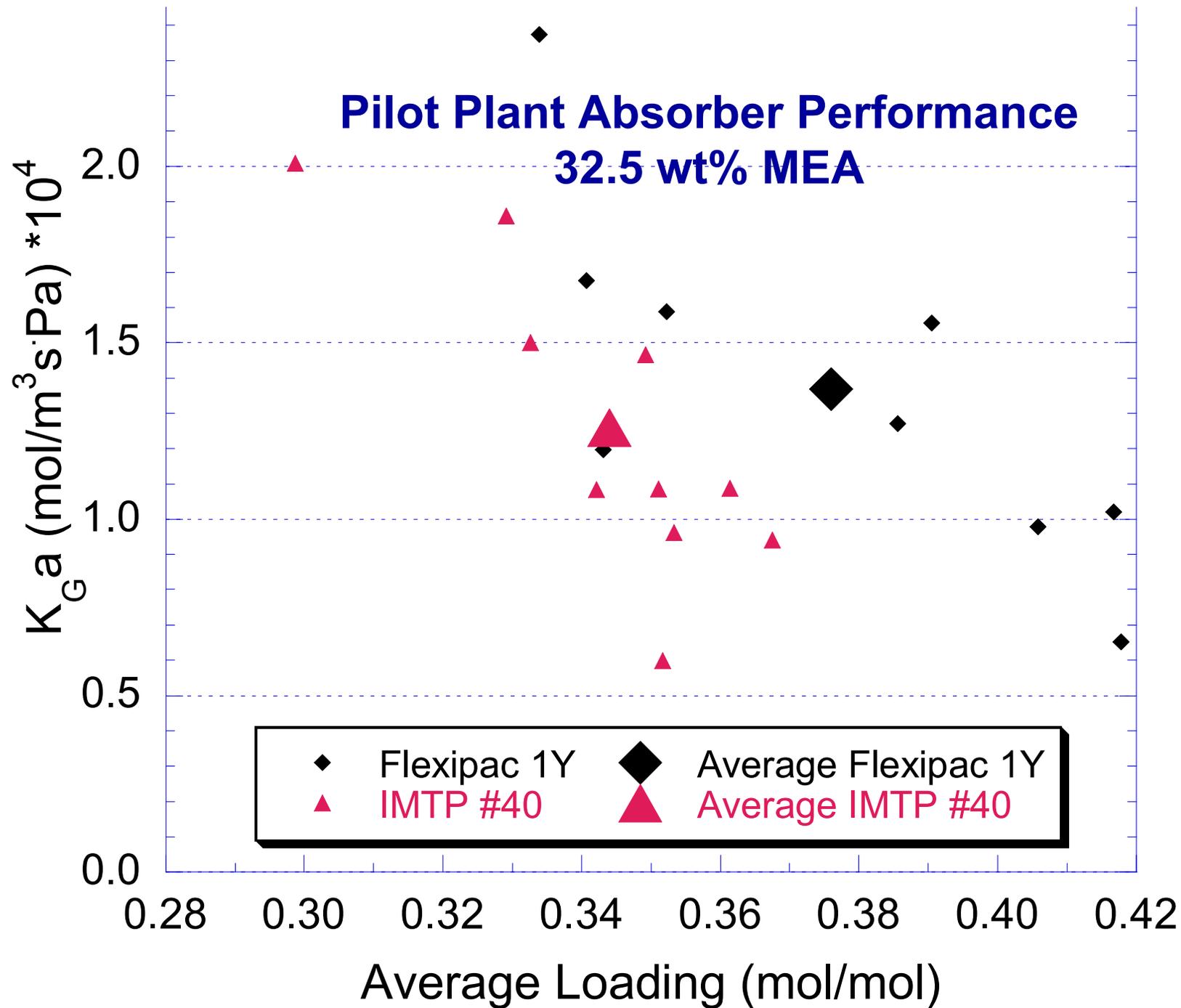
Energy for Stripping

Compression to 1000 kPa, 90% CO₂ Removal

	K ⁺ /PZ (m/m)			MEA
	6.4/1.6	5/2.5	4.5/4.5	7 m
Δh_{des} (kcal/mol CO ₂)	8	15	18	22
Rich P _{co2} * (kPa)	5	5	7.5	5
P (kPa)	Equivalent W (kcal/gmol)			
160	9.0	7.5	6.3	6.6
30	7.0	6.8	6.3	6.7
330/230/160	5.5	5.6	5.1	5.1

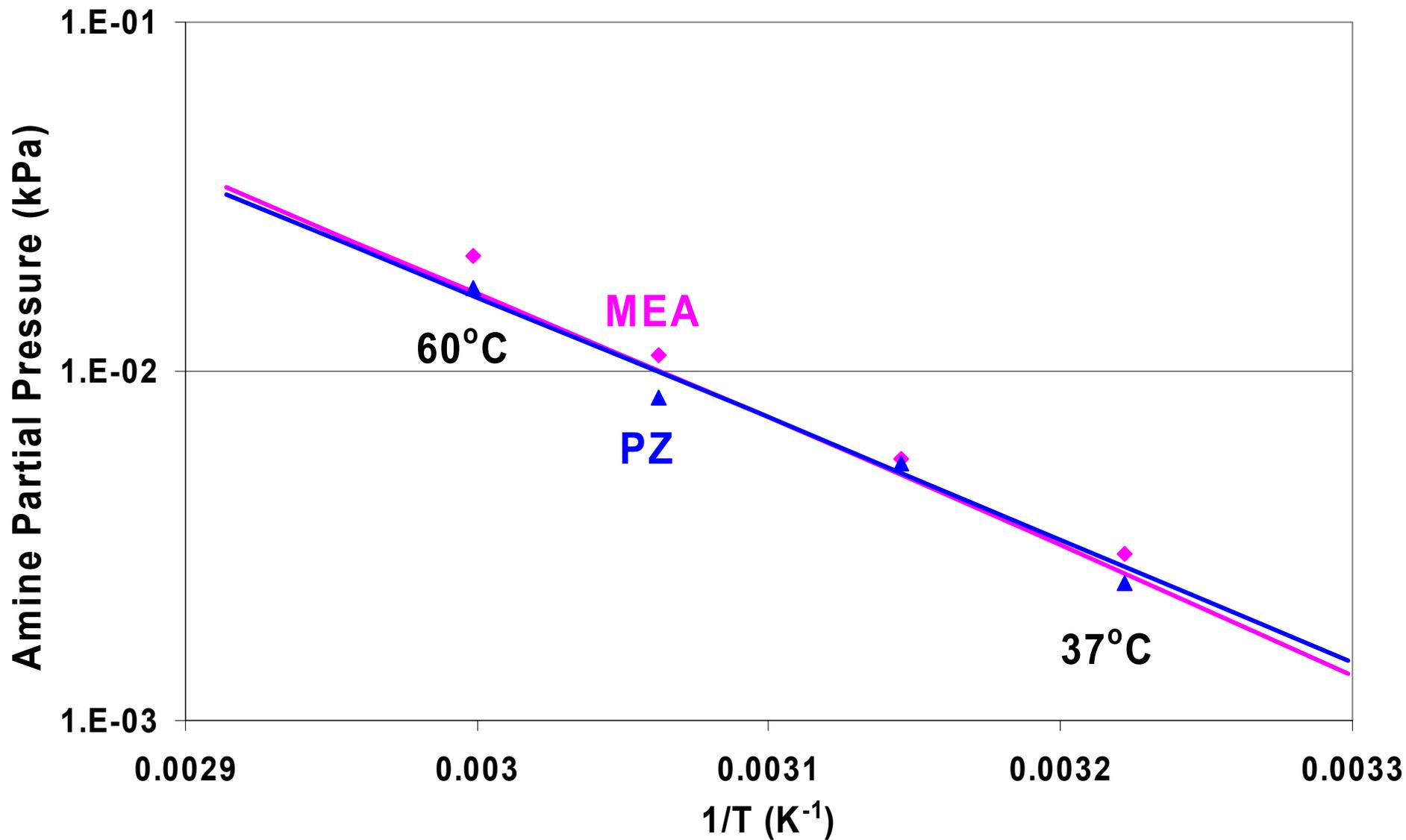
Conclusions

- 4.5 m K⁺/ 4.5 m PZ is the best solvent for energy
 - 5% less energy than 30 wt% MEA
 - 20-40% greater capacity
 - 1.3 -1.6 times greater rates
 - 20-40% greater P_{CO_2} in rich soln
- Structured Packing can reduce energy 5%
 - 20-40% richer solution
- Multipressure Stripping can reduce energy 5-20 %
- Vacuum Stripping gives equivalent energy
 - Lower T reduces degradation and corrosion

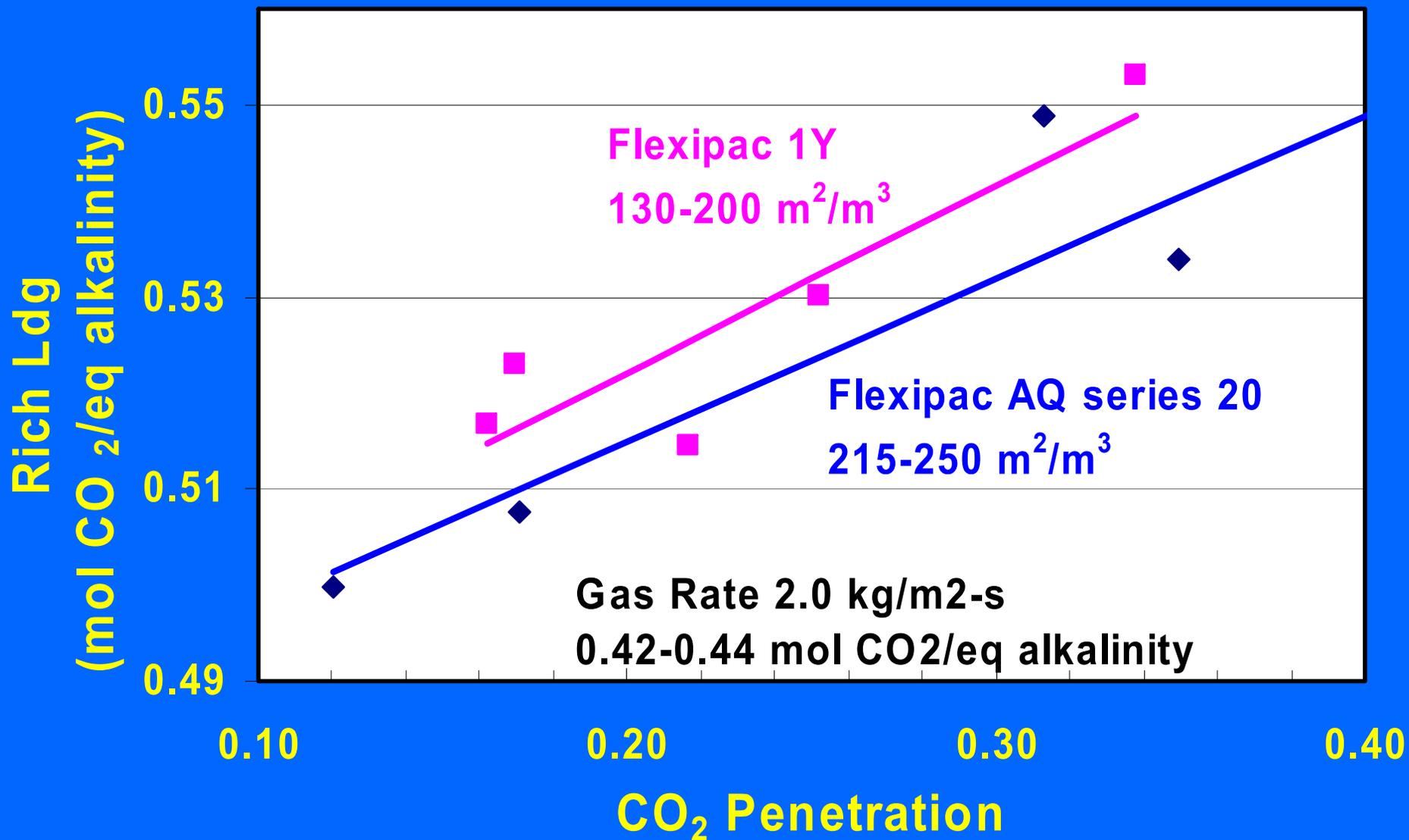


Amine Volatility

3.5 m MEA/3.6 m PZ



Absorber Performance with 5 m K⁺/2.5 m PZ



Solid Solubility (Cullinane, 2005)

