UNIVERSITY OF REGINA

"CO_2 CAPTURE AND EXACTION USING REACTIVE AMINES AND FORMULATED SOLVENTS"

INTERNATIONAL TEST CENTRE FOR CO_2 CAPTURE (ITC)

University of Regina, CANADA

www.co2-research.ca

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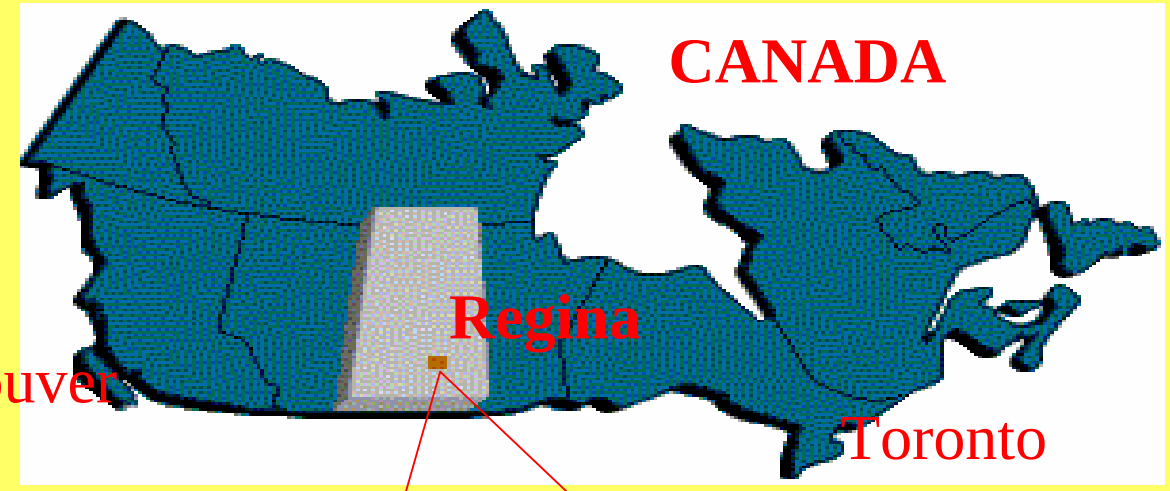
ITC

www.co2-research.ca

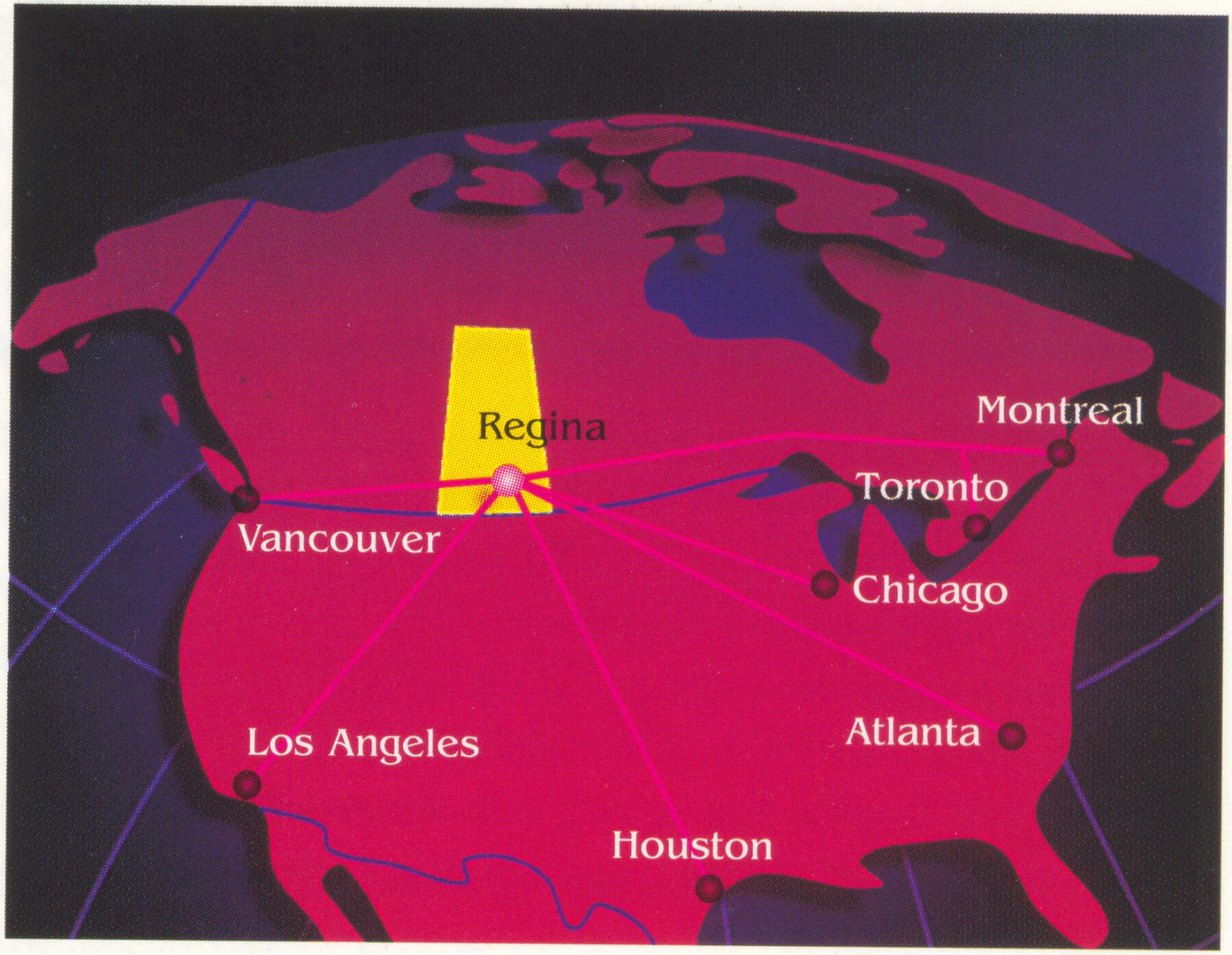
Outlines

- *Background information*
- *Pilot plants and research facilities*
- *Research team*
- *Selected results (ITC Phase I)*
- *Current and future work plan (Phase II)*
- *Fundamental research at ITC*
- *Discussions*

International Test Center for CO2 Capture (ITC)



ITC


Regina
Montreal
Toronto
Vancouver
Chicago
Los Angeles
Atlanta
Houston

REGINA, SASKATCHEWAN, CANADA

U of Regina's Strategic Goals

- ***"Energy and Environment"*** one of the key important strategic research goals
- Major strength in Climate Change Research
- Develop research excellence:
  - Prairie Adaptation Research Collaborative (PARC)
    - **www.parc.ca**
  - Petroleum Technology Research Centre (PTRC)
    - **www.ptrc.ca**
  - IEA Weyburn Monitoring Program for CO2 EOR & Storage
    - **www.ptrc.a**
  - ITC – CO2 capture Development Program
    - **www.co2-research.ca**
  - Hydrogen & Bio-fuel Research Program **(www.htcenergy.ca)**

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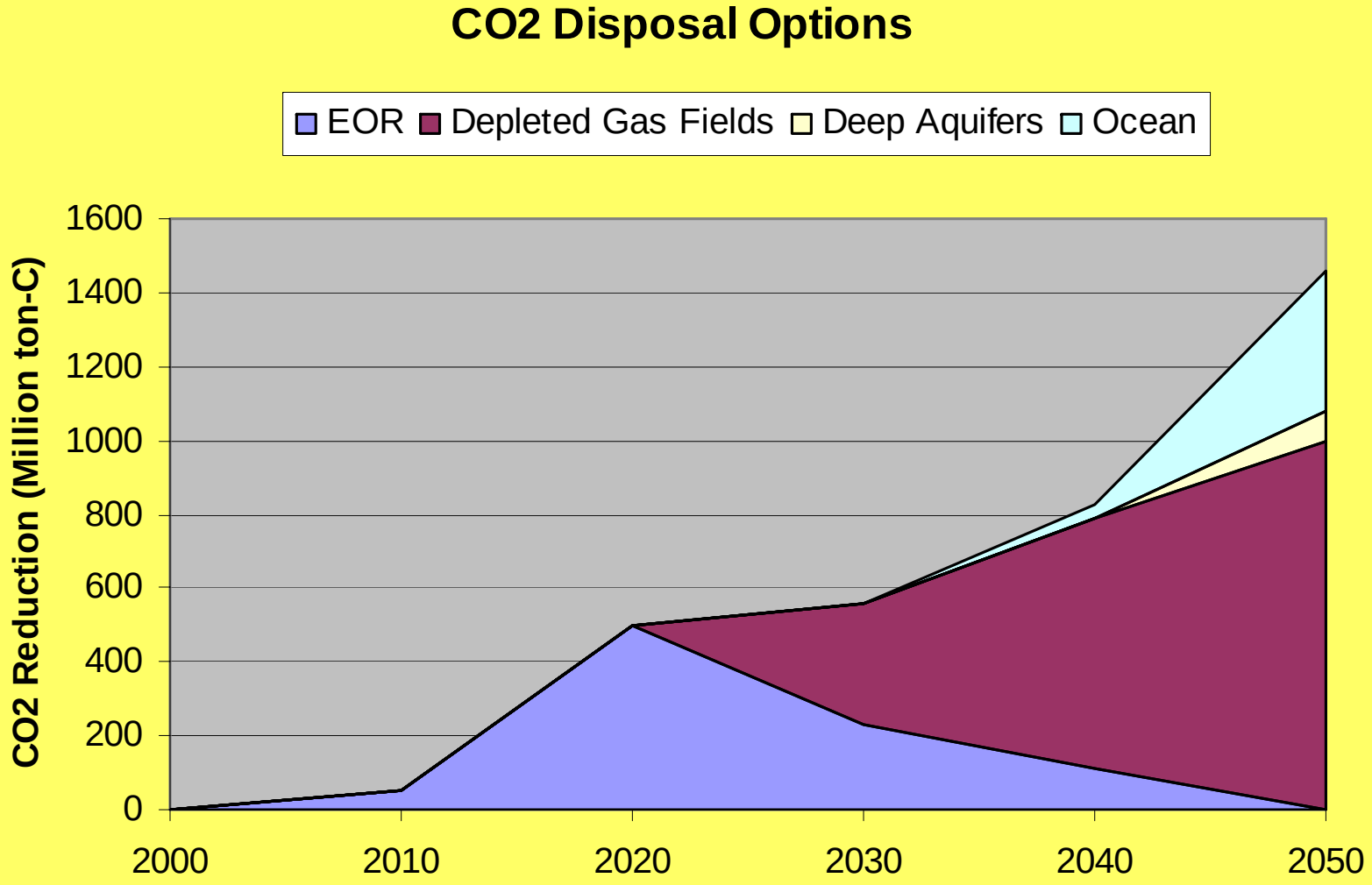
CO_2 Mitigation Options

- Pre combustion
  - Energy efficient systems
  - Renewable Energy sources
  - Non-carbon fuels
  - Etc.
- Post combustion
  - **Carbon dioxide capture**
  - **Carbon dioxide Storage**
  - Carbon dioxide conversion
  - Etc.

DNE-21 Model Predictions (Kaya, 1994)



The International Test Centre For Carbon Dioxide Capture

UNIVERSITY OF REGINA

ITC

GREENHOUSE GAS TECHNOLOGY CENTRE (GTC)

U of R Process Systems Laboratory

(Fundamental Research)

International Test Centre for CO_2 Capture

(ITC)

CFI

Sponsored Research:

ITC – Industry Consortium

Contract Research

University Research

UNIVERSITY OF REGINA

AS ONE WHO SERVES

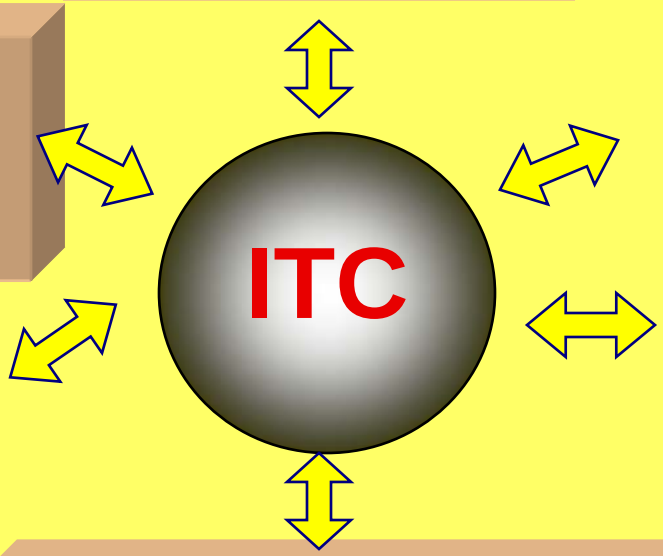
ITC

Partnerships Across Sectors

ACADEMIA
- *U of Regina*
- U. of Waterloo
- UBC
- U of Calgary

COAL
- Luscar

ENERGY & ENGINEERING
- *HTC Energy Inc. ***
- *B & W, USA ***
- Fluor Daniel ?



POWER UTILITIES
- SaskPower
- TransAlta
- *E – ON, UK ***

OIL & GAS
- Nexen Energy Inc.
- EnCana
- PetroBras
- *Saudi ARAMCO ***

GOVERNMENTS
- Canada -Natural Resources Canada
- Government of Saskatchewan
- Government of Alberta
- *Japan – RITE ***

ITC
International Test Centre
for CO2 Capture

Potential New Members

- China
- Mexico
- Korea
- SNC
- *More new members are welcome.*
- Etc.

ITC Unique Features

Testing Facilities

Technology Demonstration Pilot Plant:

(*CO_2 capture pilot unit at Boundary Dam Power Station near Estevan*)

Multi-Purpose Technology Development Pilot Plants:

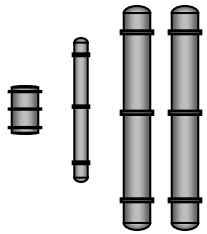
(*at University of Regina*)

Research Facilities:

(*at University of Regina*)

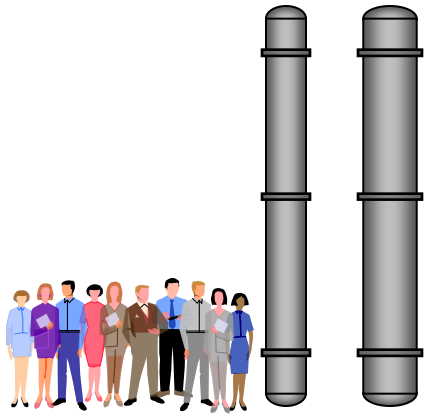
U of R
Research Facilities

(Absorption units / reactors)



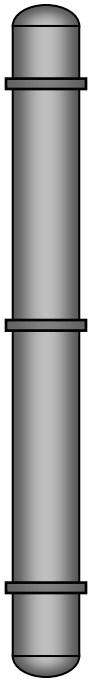
U of R
Technology development

(10-m H×12 in. ID)
(10-m H×18 in. ID)

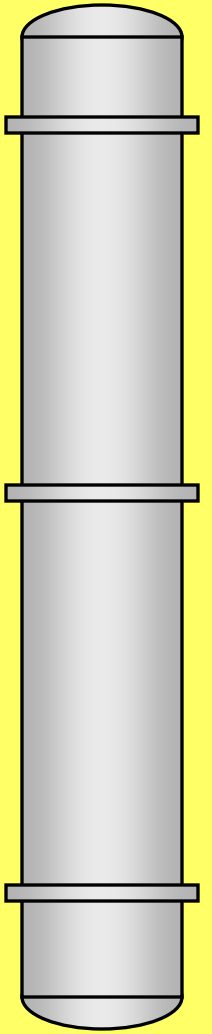


Boundary Dam
Semi-commercial testing

(20-m H×18 in. ID)



Commercial unit



ITC Recent Investments

- Over 20 million funding has been invested in ITC's research infrastructures
  - *$5.2 million pre-commercial scale demonstration plant at Boundary Dam*
  - *$3.3 million Multi-purpose Technology Development Plant at the U of R*
  - *$1.2 million bench scale facilities at the U of R*
  - *$4.5 million analytical and computer facility from Canada Foundation for Innovations (CFI)*
  - *$5 million from NSERC general grants over the past 10 years*

Technology Demonstration Plant

Objectives:

- To test the technical and economic feasibility of a promising process prior to commercialization.
- To evaluate the possibility for process integration with the overall system.
- To evaluate the economic feasibility of various chemicals and components proposed after laboratory and pilot-plant studies.

BOUNDARY DAM UNIT

- Coal-fired flue gas
- Capacity - 4 - 8 ton / day of CO_2 (99% +)
- Flue gas flow rate - 500,000 scf / day
- ID = 18”
- Height = 20 m

Multipurpose Technology Development Pilot Plant

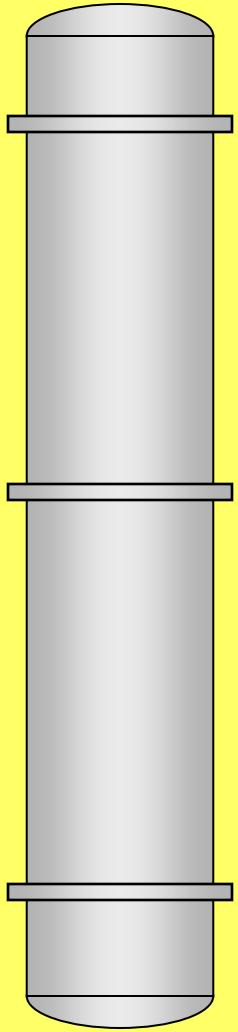
Key Researchers

- *11 Key researchers + 50 Research Staff*
  - *Dr. Paitoon (PT) Tontiwachwuthikul*
  - *Dr. Amit Chakma*
  - *Dr. Malcolm Wilson*
  - *Dr. Gordon Huang*
  - *Dr. Raphael Idem*
  - *Dr. David De Montigny*
  - *Dr. Amy Veawab*
  - *Dr. Amr Henni*
  - *Dr. Andy Aroonwilas*
  - *Dr. Nader Mahinpy*
  - *Dr. Ahmed Adoudhier*
  - *Plus 50+ Researchers (Engineers, PDF's, Master & Ph.D. Students, Technical Support staff, etc.)*

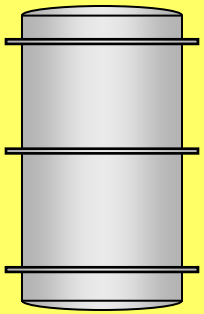
Research Team

Our Ultimate Goals

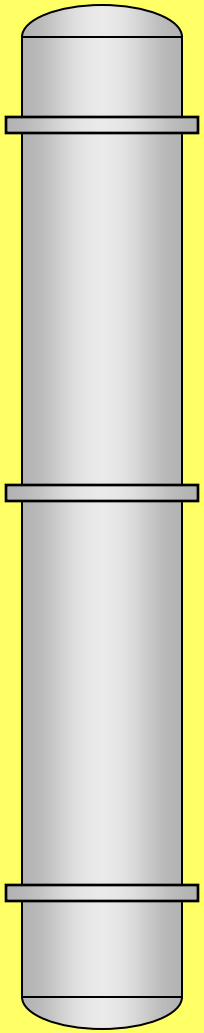
Base Case



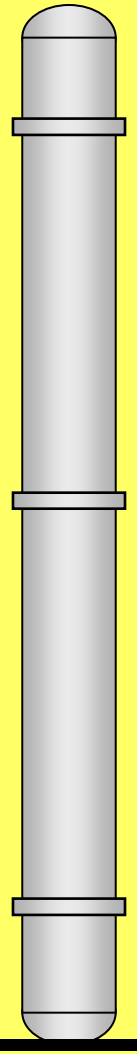
1. Increase mass transfer of packing by 4 times



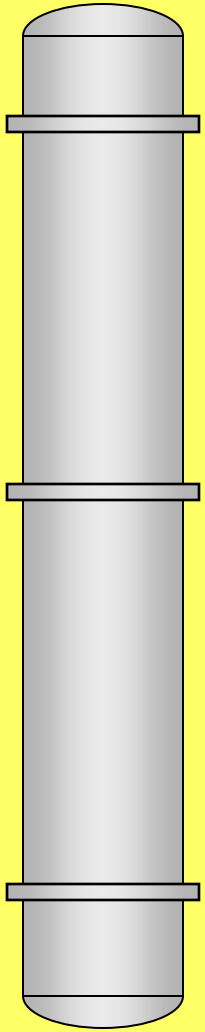
Base Case



2. Increase the solvent separation capacity by 4 times



Base Case



R
&
D

???

Improved packing and solvent - Combine effect ?

Major Goal:

- Cost reduction for CO_2 capture

Where are we?

- Capture cost: $ 50 per ton CO_2 (AOSTRA Report)

$30 - $35 (TransAlta)

ITC Activities

$15 (Gov. Canada CO_2 credit)

Current Status of Technology

- Reactive solvents (5 to 9 Molar)

% Reduction	***Energy Consumption:***	
	90,000	3 Molar-based solvent
	70,000	5 Molar-based solvent
50%	50,000	***New Generation Solvents***
	40,000	*ITC Testing Program*
1/3	30,000	

Combined Effects

- Solvent circulation: Reduced by 50 - 60%
- Column size: Reduced by 50% (packing volume)

Potential Cost Saving (Rough estimated)

- US$ 30 (Based)
  - US$15 (Capital) ……. 75% ….. US$ 12.5
  - US$15 (Operation) …. 50% ….. US$ 7.5

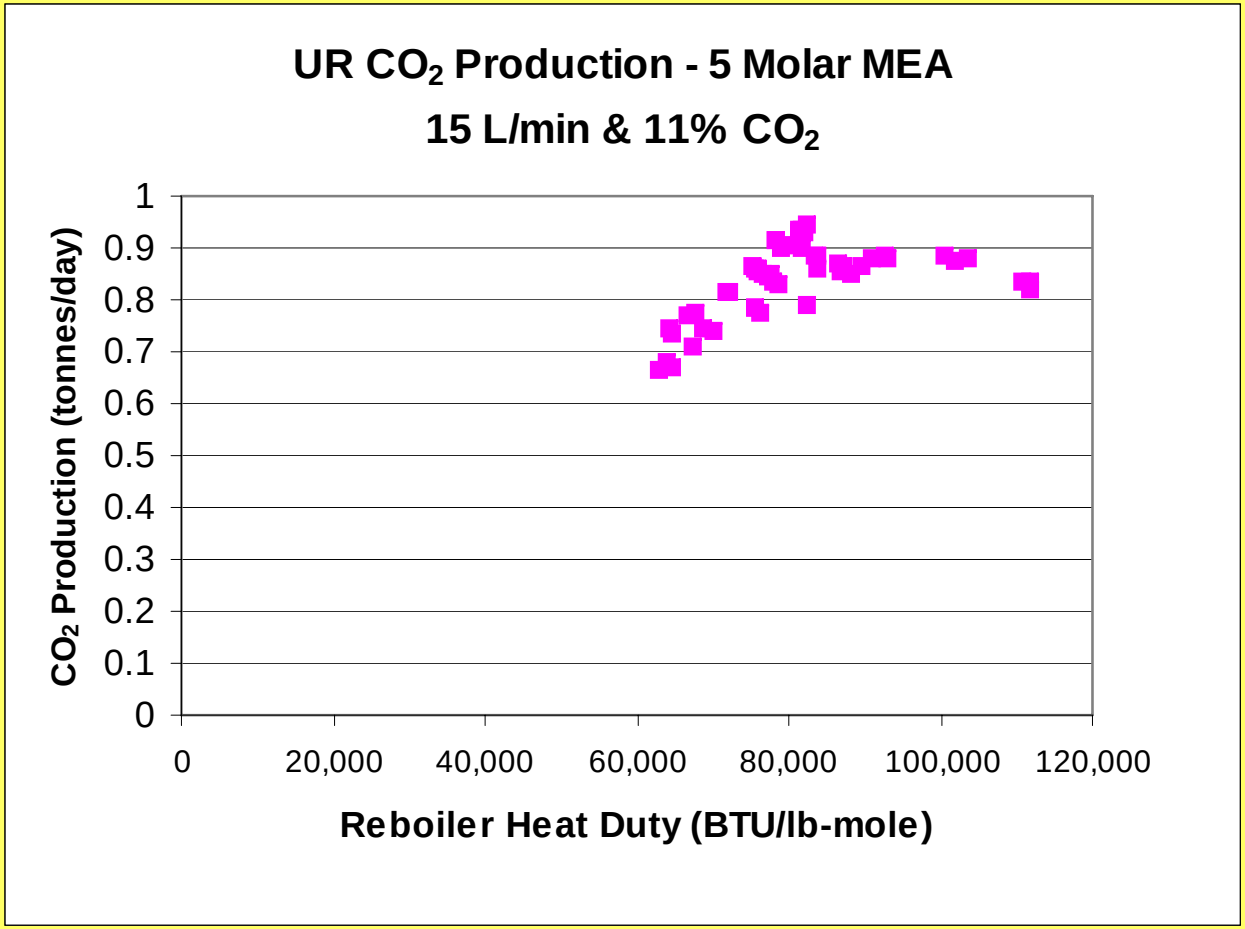
US$ 20 ± $5

Some selected results from ITC Phase I

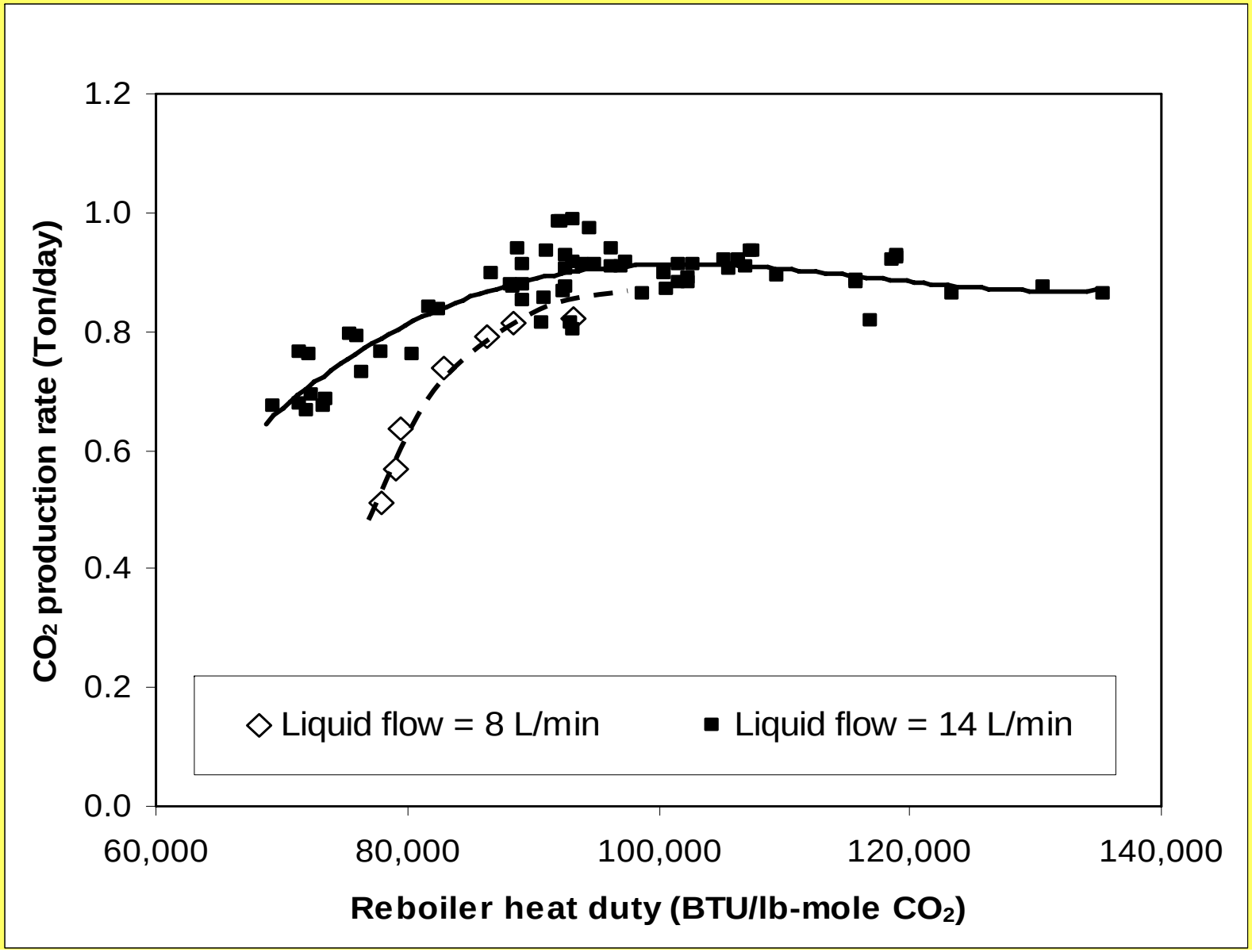
Solvents and Technologies

- *Fluor Solvent Technology*
  - *(standard and current technology – 5M MEA with additives)*
- *Extra high concentrations*
  - *(7 to 9 M)*
- *Formulated solvents (MEA/MDEA mixtures)*

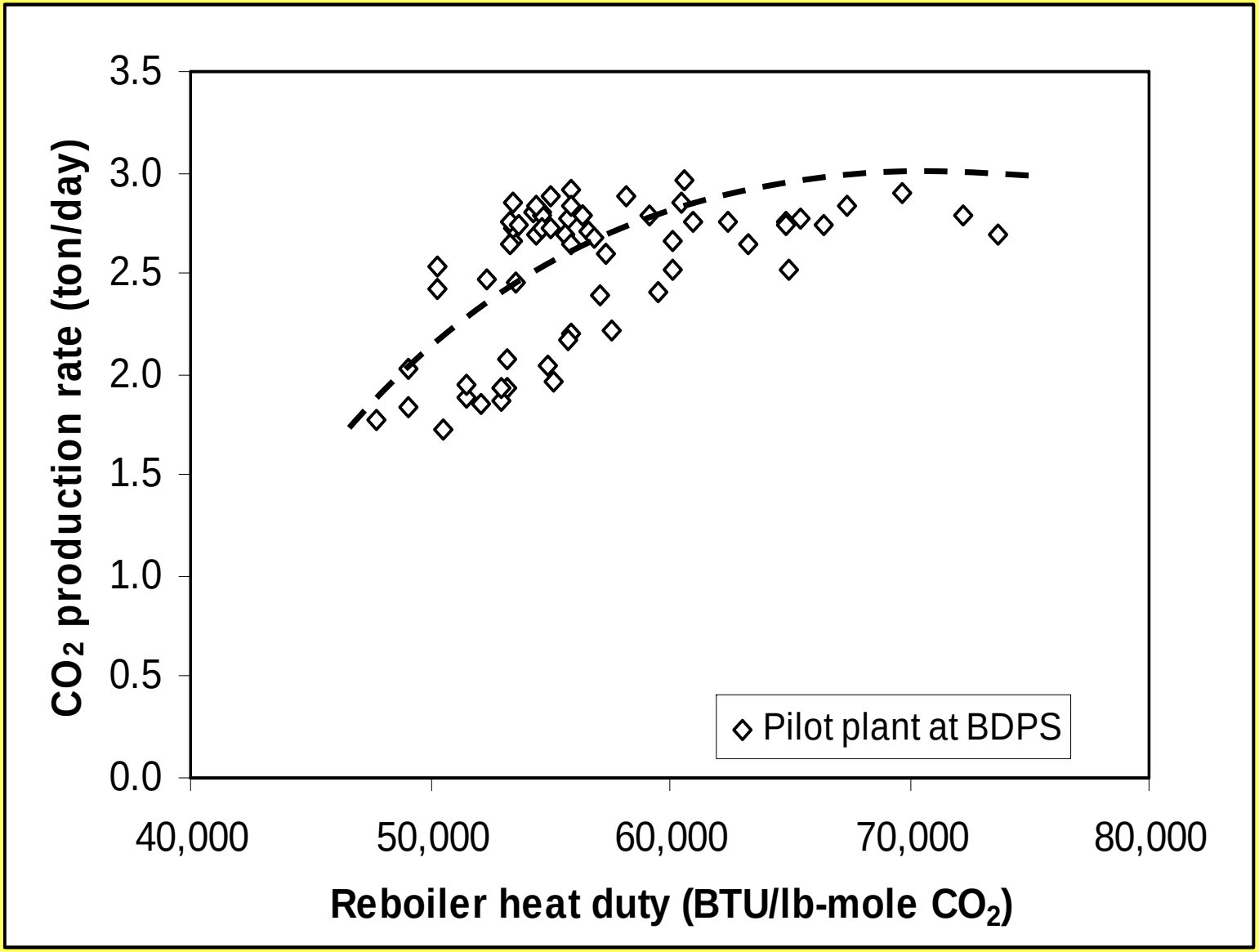
UR CO_2 Production: Effect of Increasing Reboiler Heat Duty



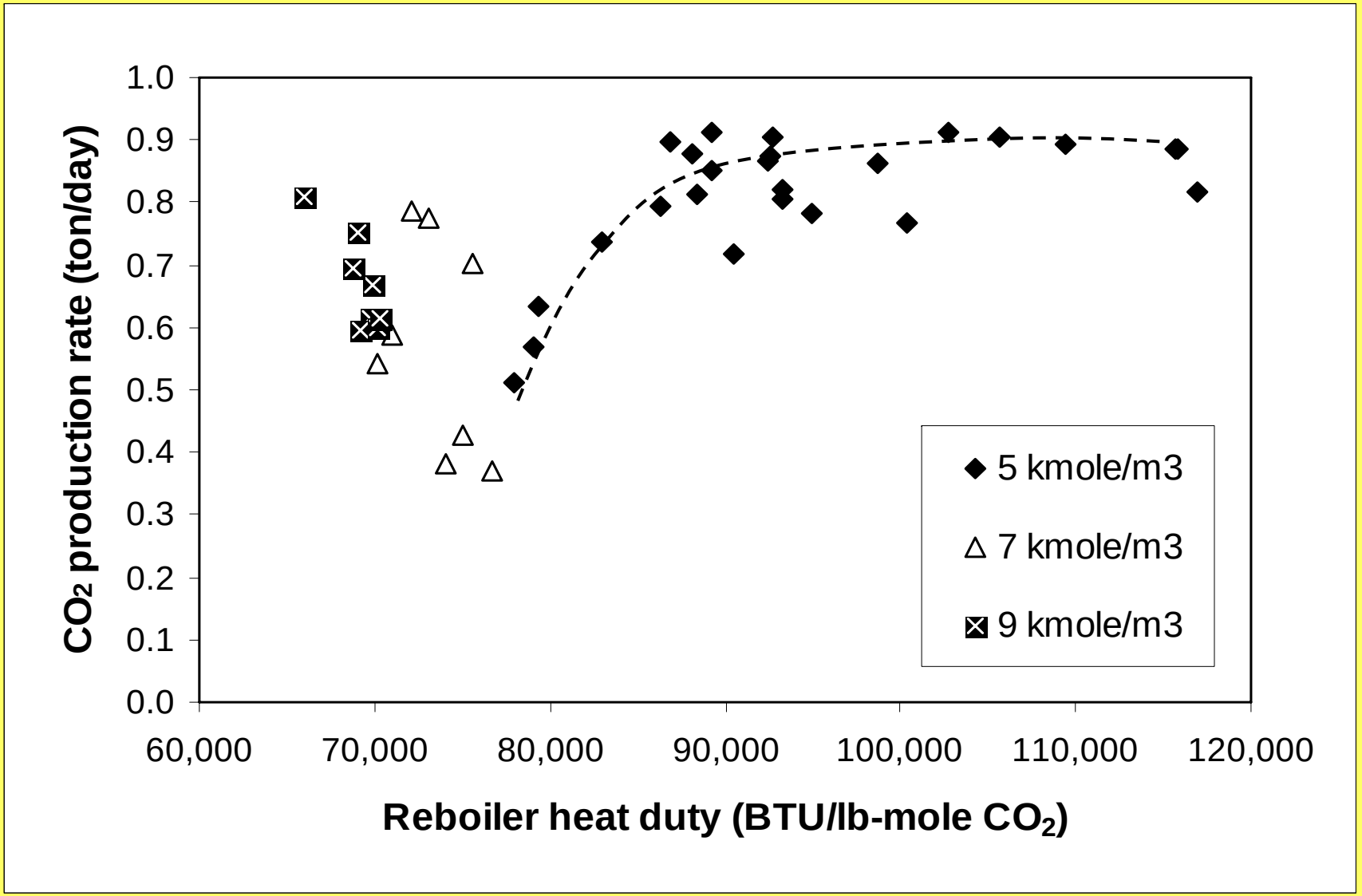
UR Pilot Plant (5 kmol/m3 MEA)



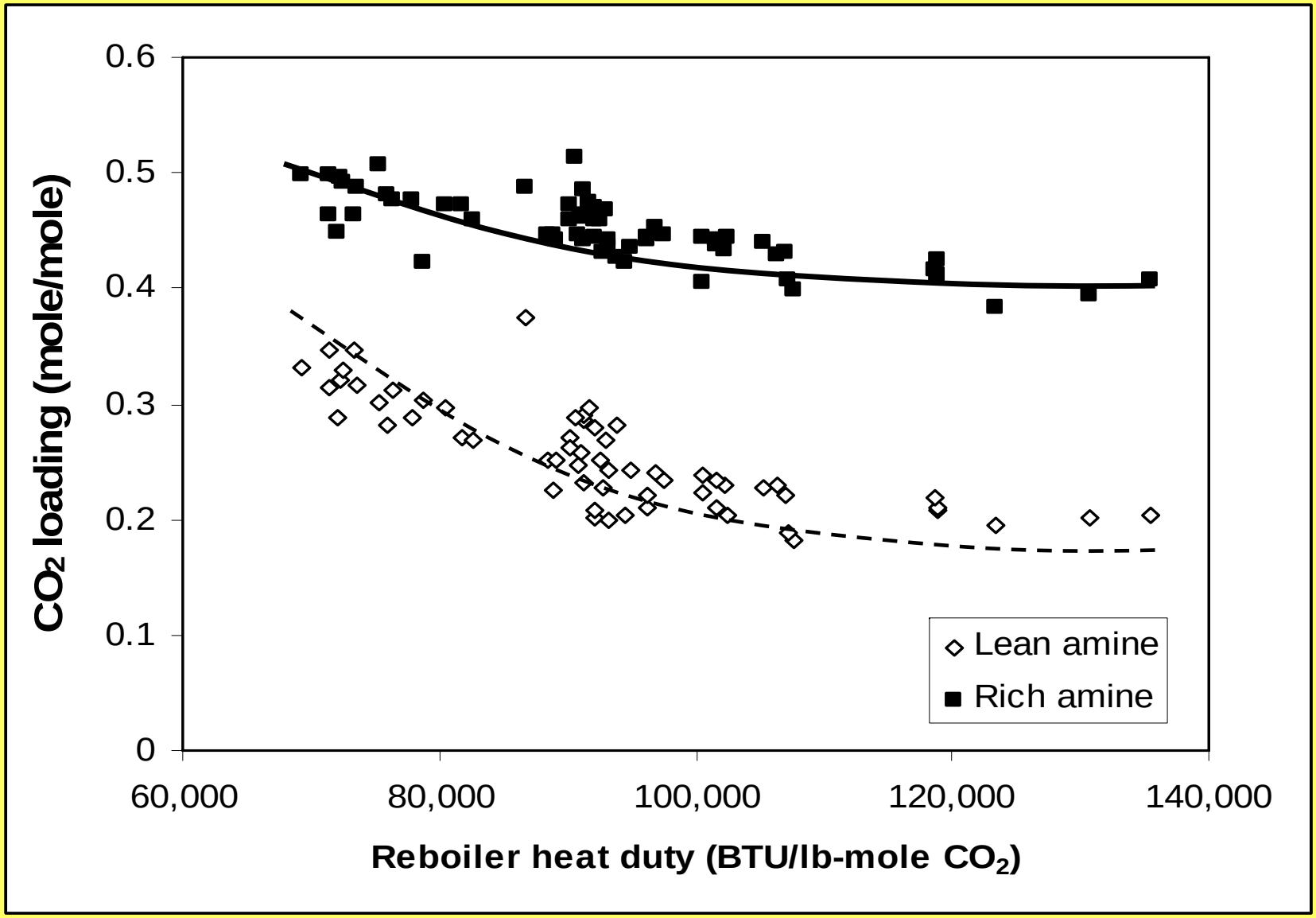
BDPS Pilot Plant (5 kmol/m3 MEA)



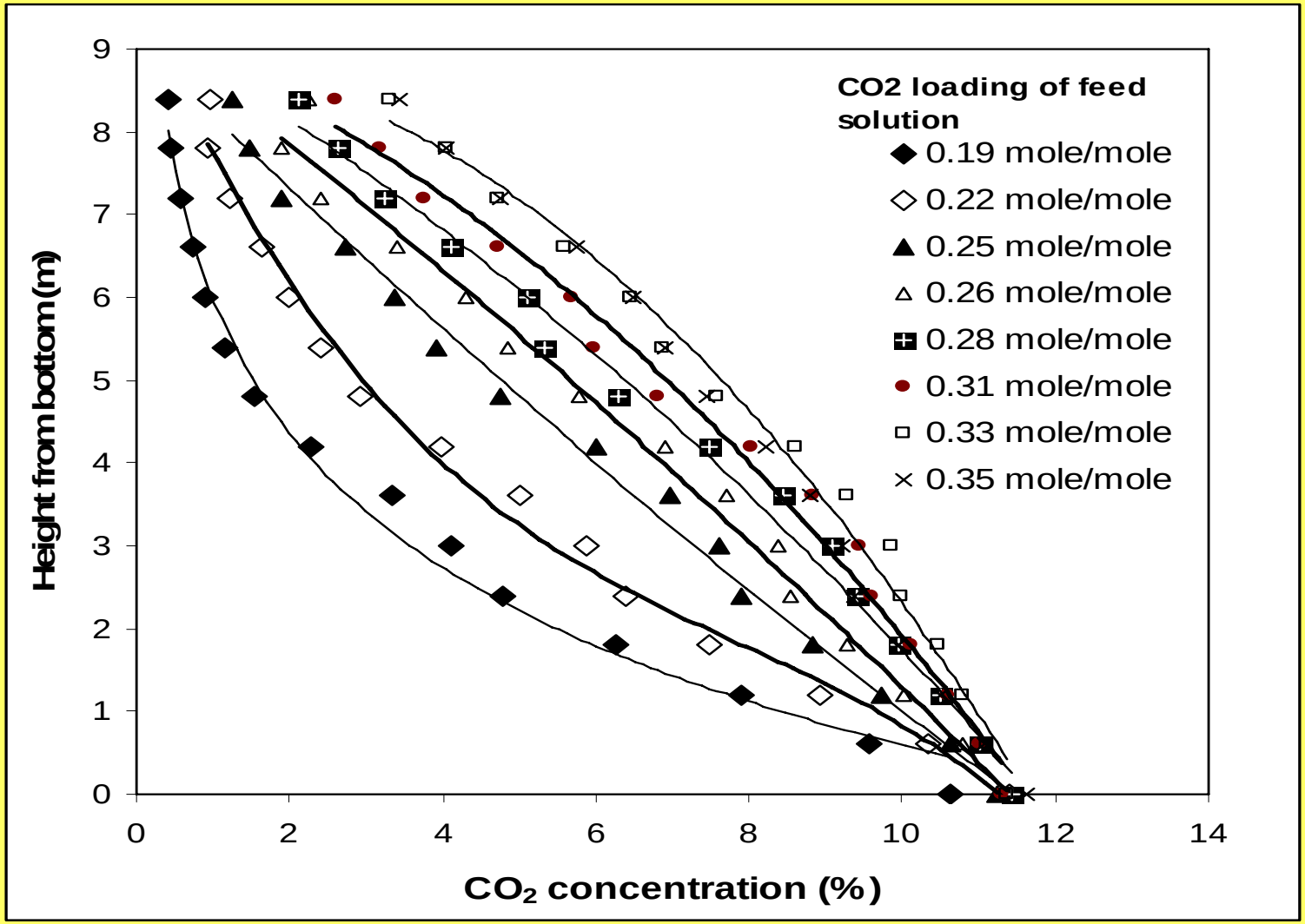
Effect of Solvent Concentration



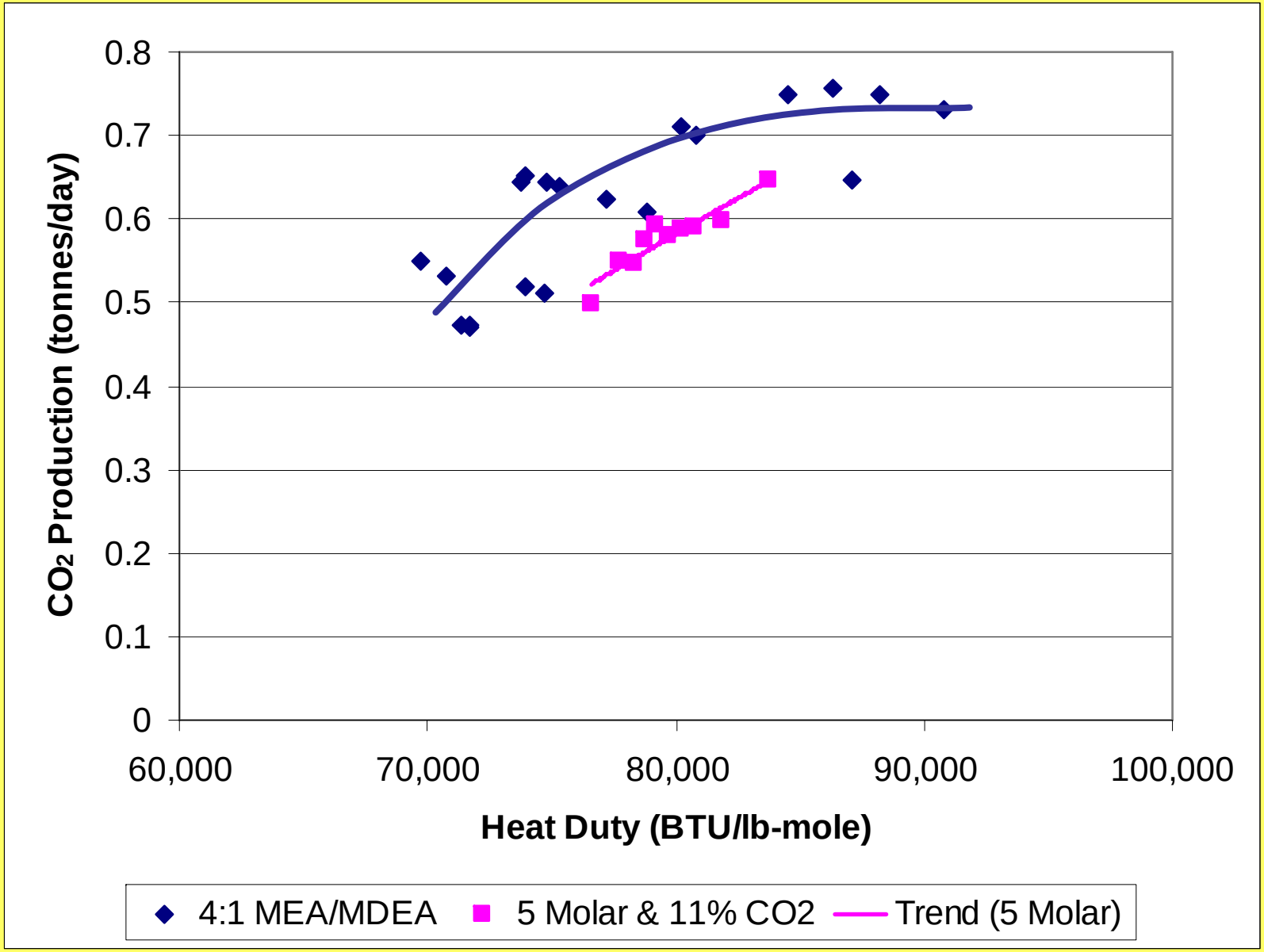
Effect of CO2 Loading in Reactive Solutions



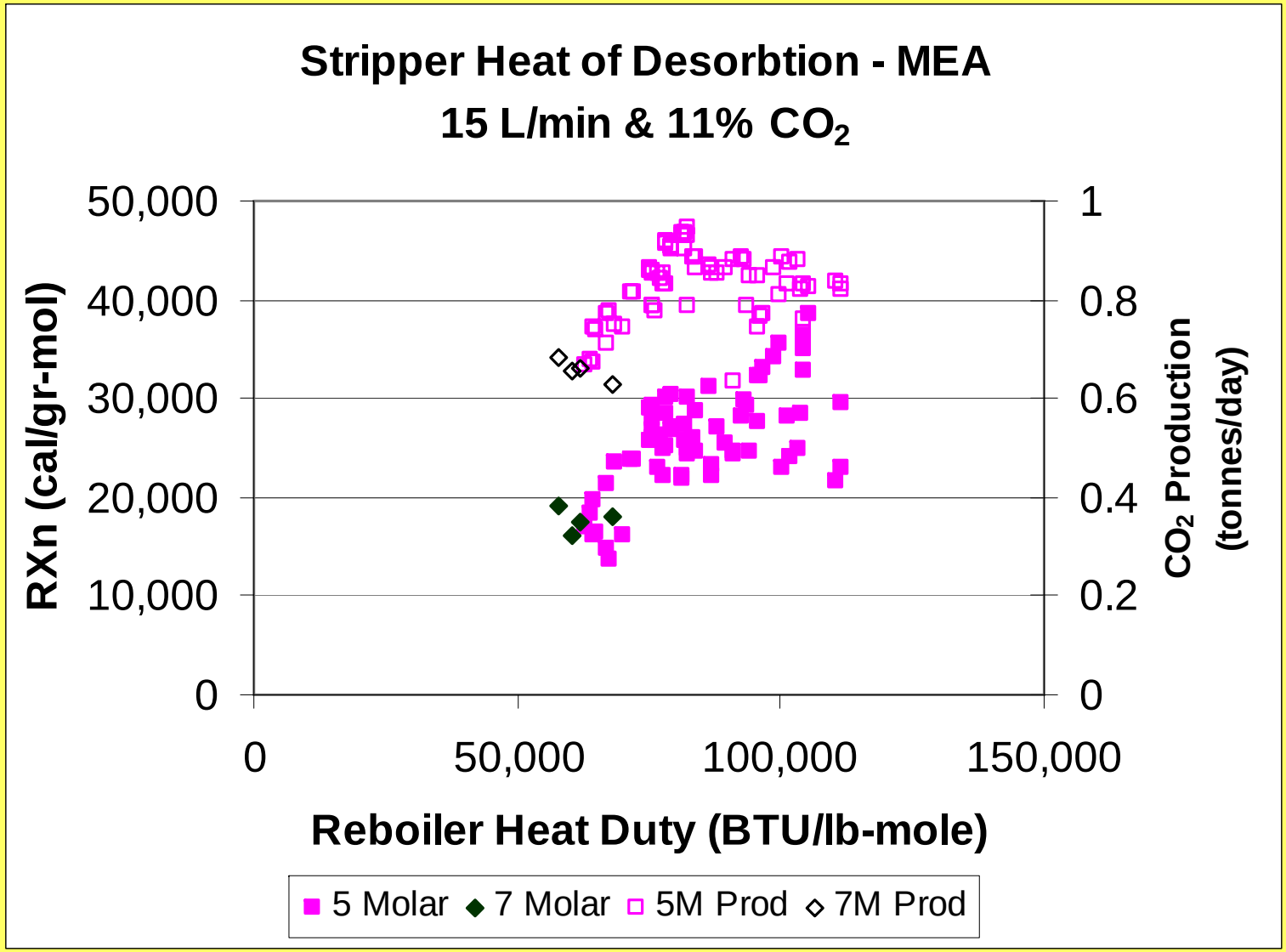
CO2 Concentration Profiles (UR Pilot Plant Studies)



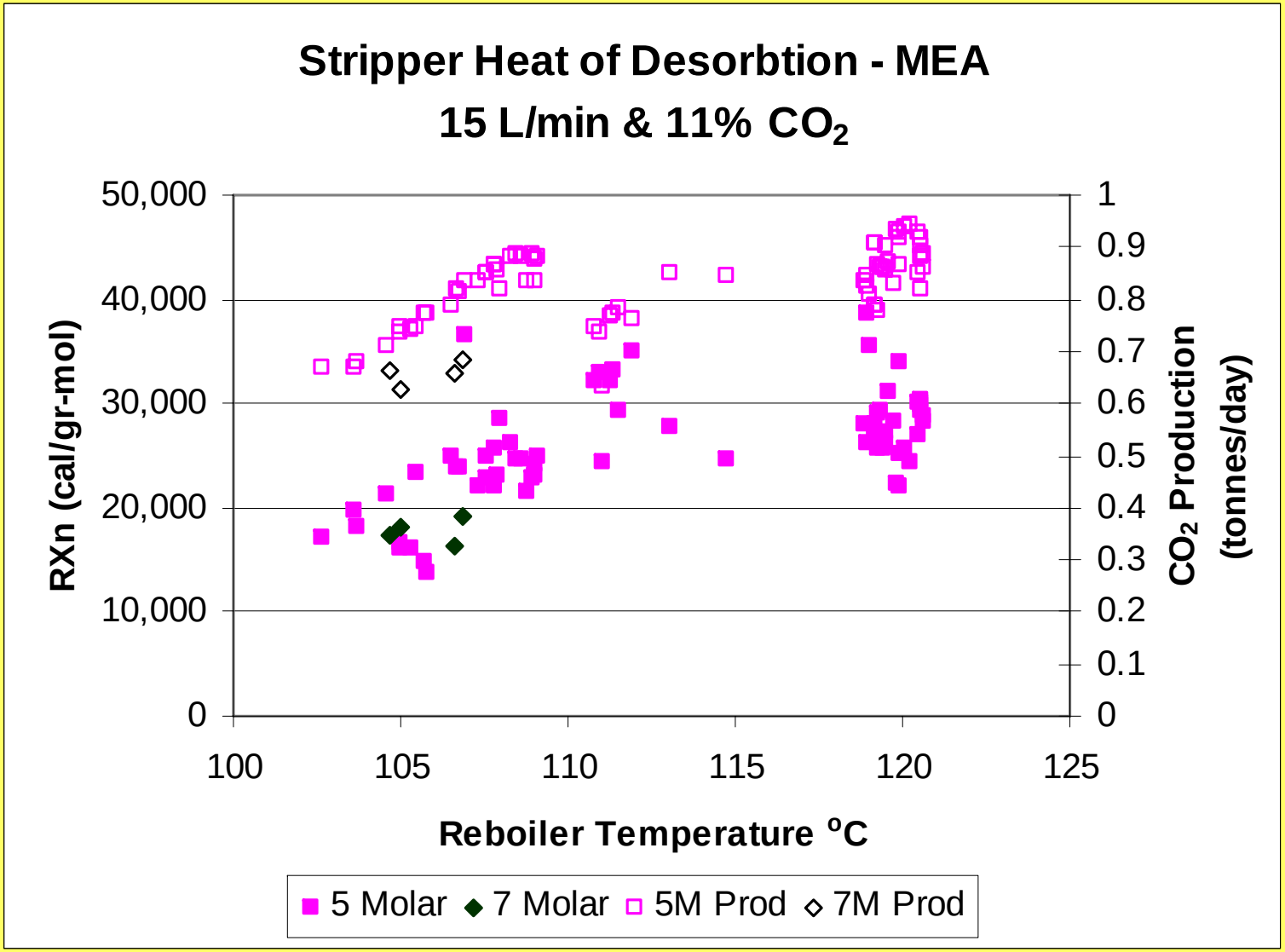
CO2 Production using 4:1 MEA/MDEA Mixed Solvents



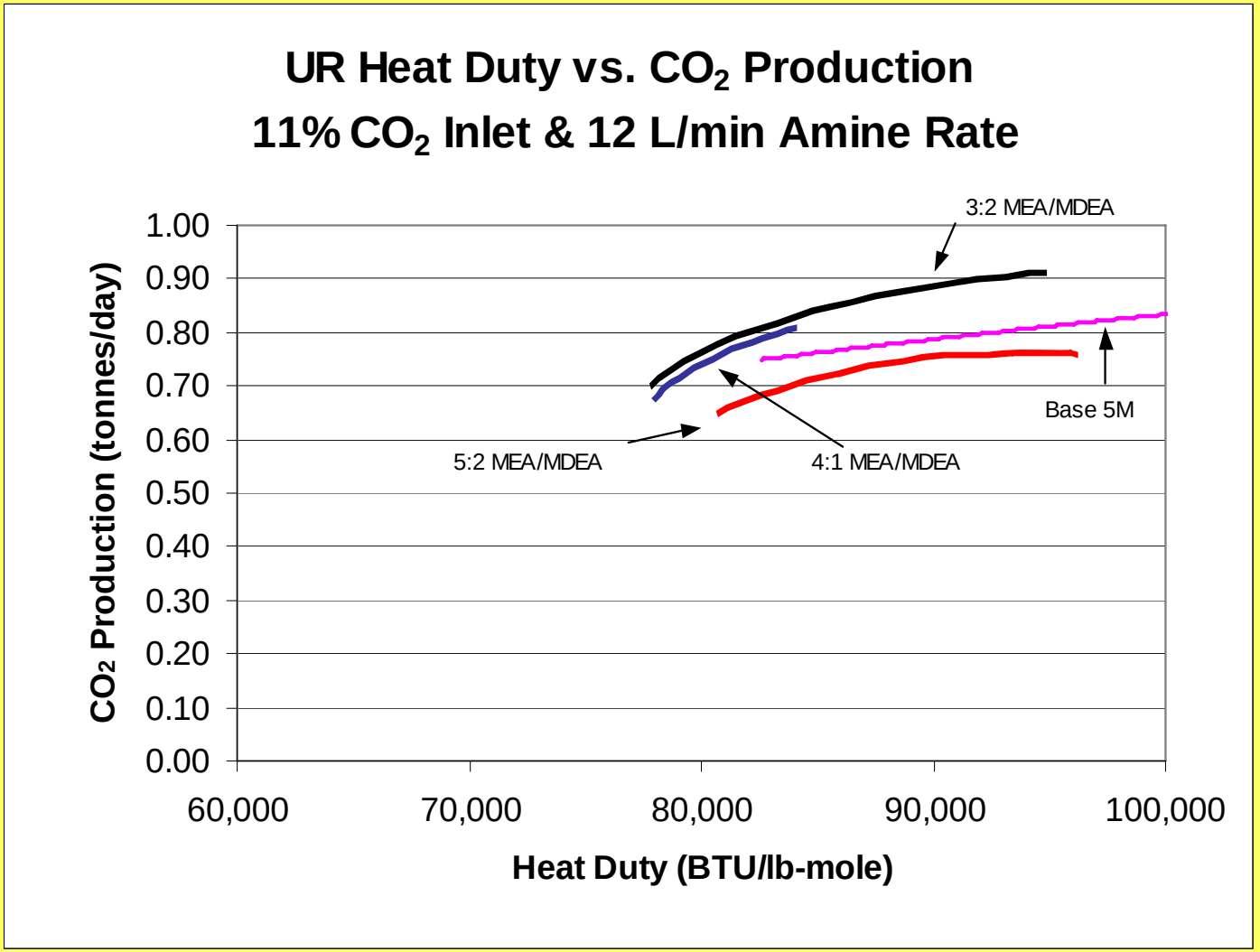
Comparison of Stripper Heat of De-sorption and Production over Heat Duty Range



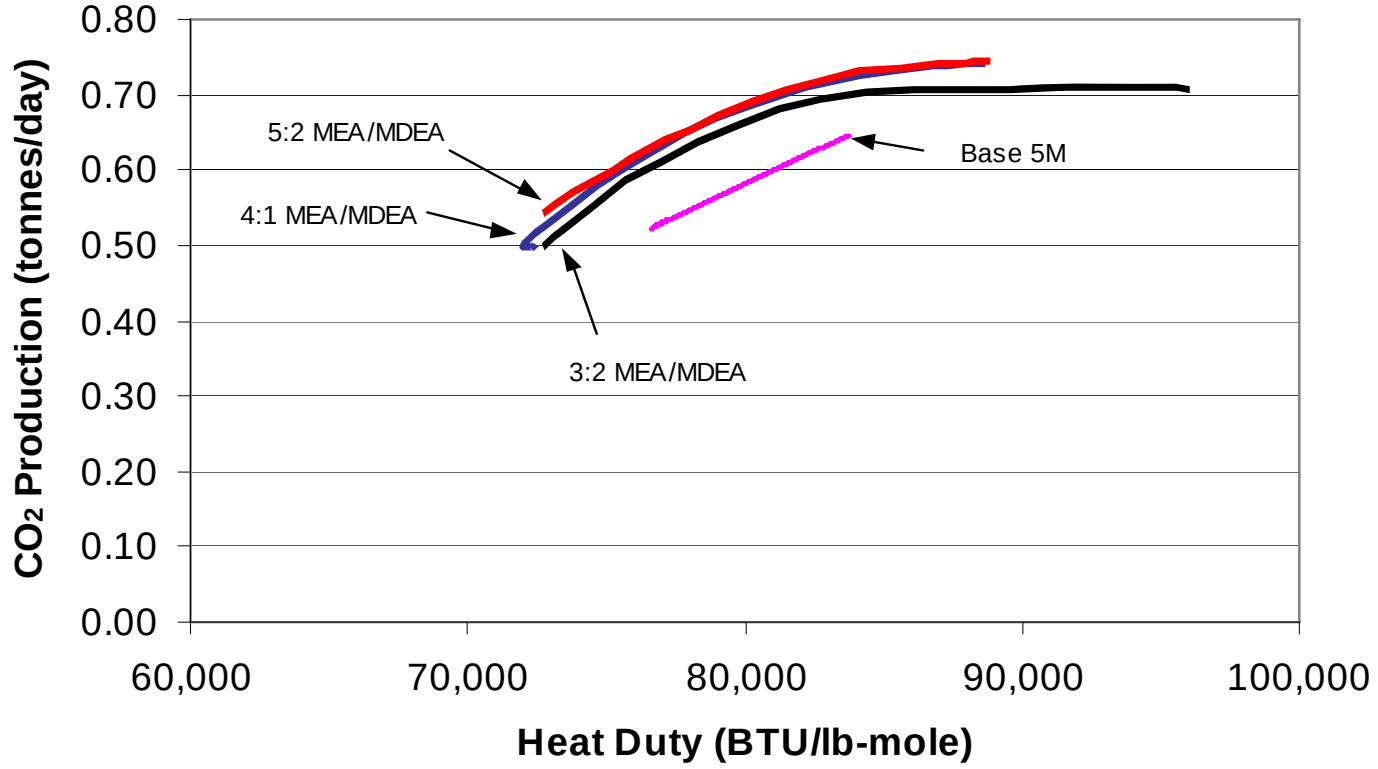
Effect of Stripper Heat of Desorption and Production over Reboiler Temperature Range



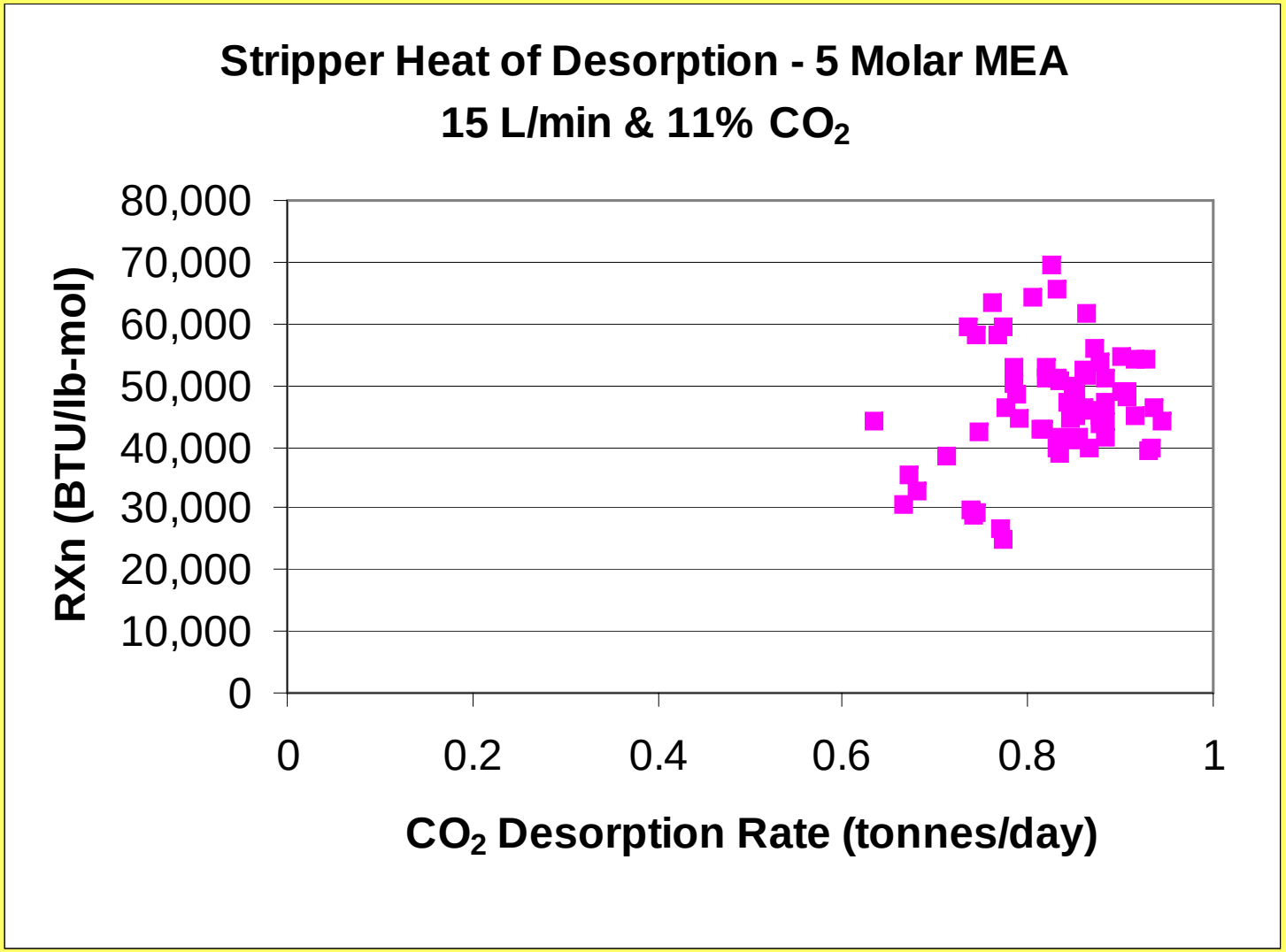
UR CO_2 Production with MEA/MDEA vs. Reboiler Heat Duty



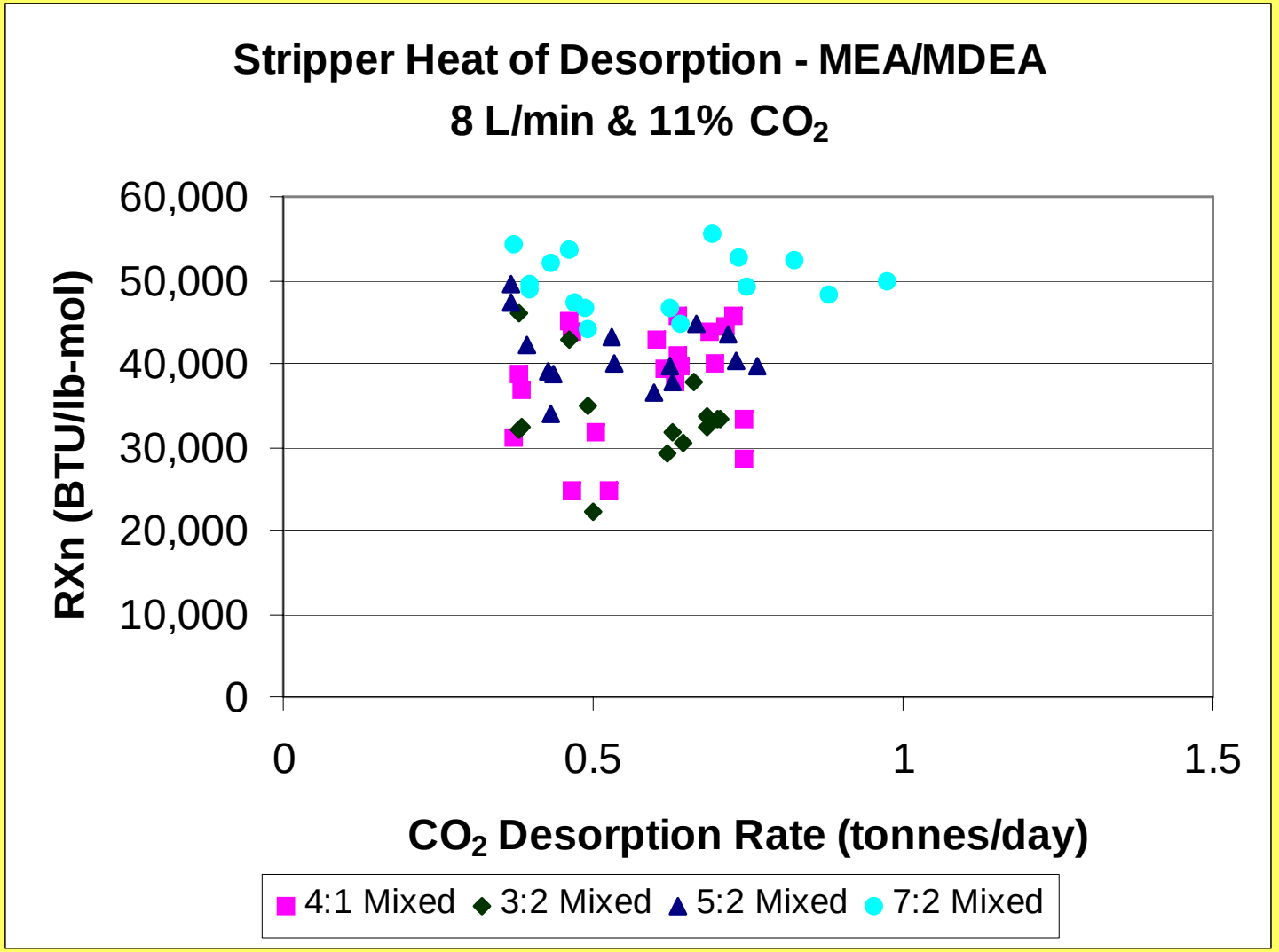
UR Mixed MEA-MDEA Solvents: CO_2 Production as a Function of MEA/MDEA ratio



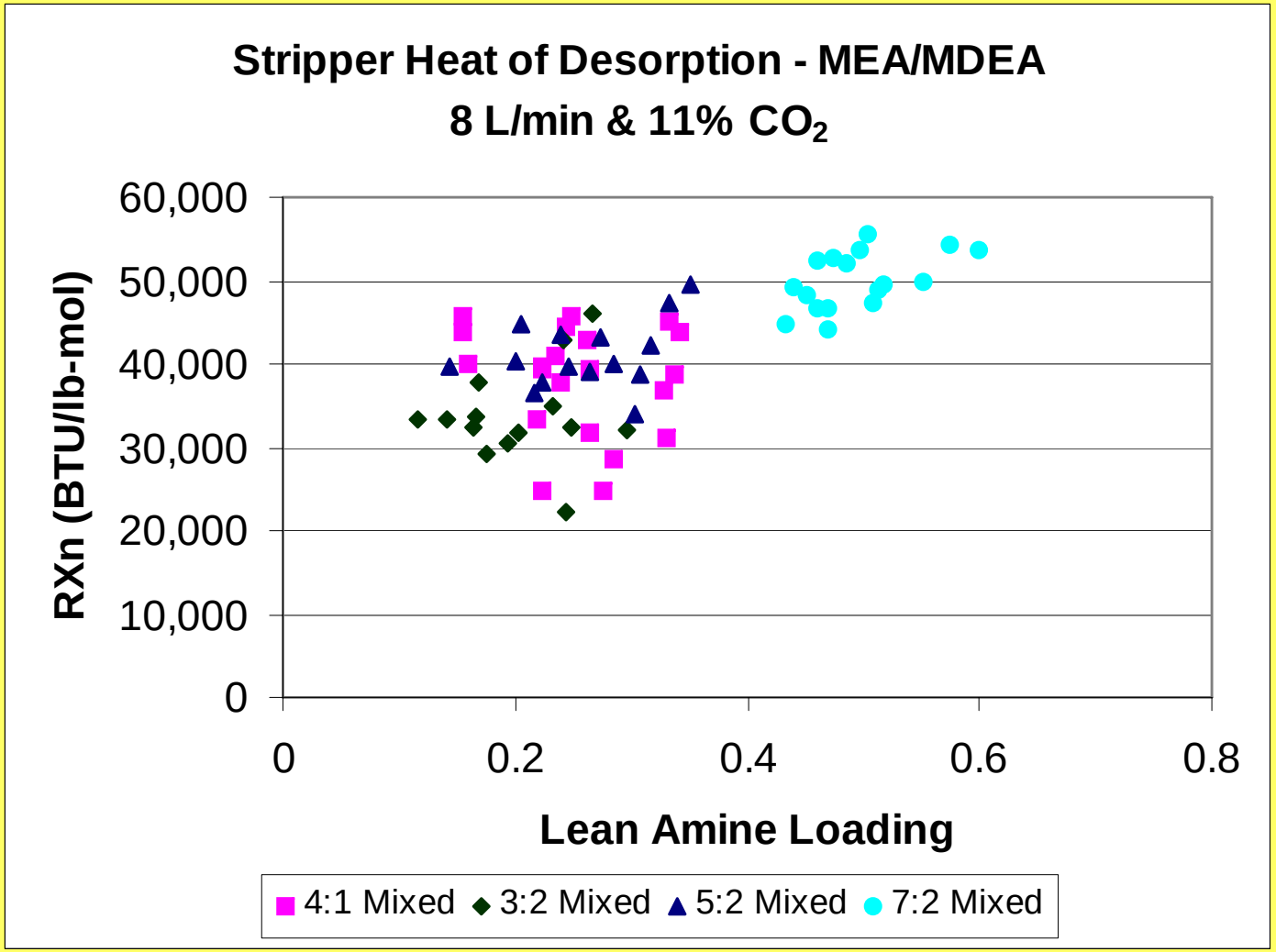
UR Stripper Heat of Desorption vs. Production Rate



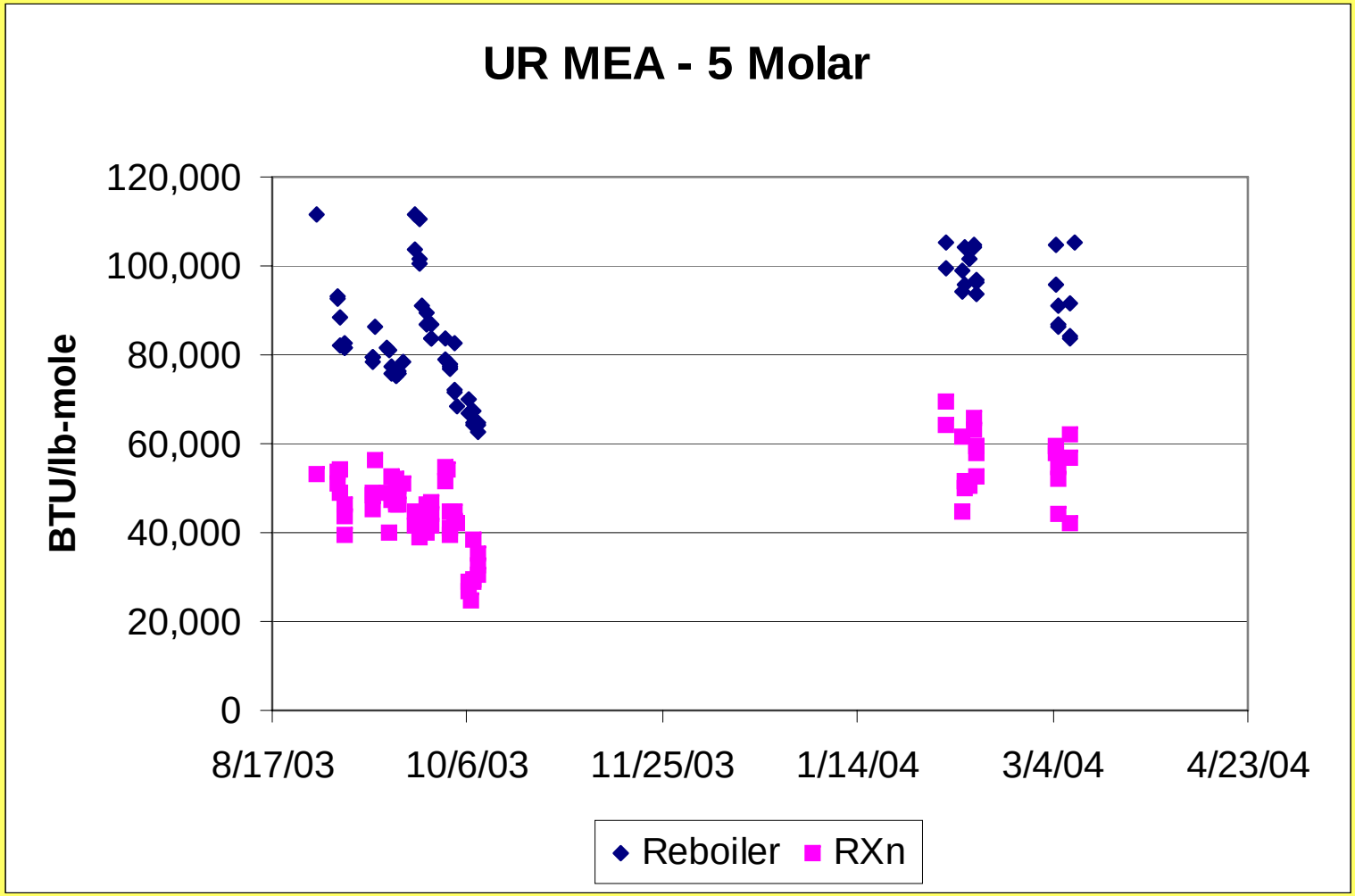
UR Stripper Heat of Desorption vs. Production Rate



UR Stripper Heat of Desorption vs. Lean Loading



Reboiler vs. Stripper Desorption Energy Comparison



ITC Phase II :
Work Plans (2005 – 2009)

Task 1

- Significantly reduce the base and optimized cost of using "Designer Solvents" for CO_2 capture processes:
  - *Extra high concentration solvents with additives*
  - *Formulated mixed solvents*
  - *Designer solvents (e.g. PSR, etc.)*
  - *Novel Solvents developed by the University of Regina*

Task 2

- Optimize process conditions/procedures through:
  - *modifications made to the operating conditions of the conventional MEA process*
  - *modifications made to the process configuration such as split flow and steam injection*

Task 3

- System analysis and integration of promising technologies, process configurations, and operating procedures
  - *Examine improved technologies such as designer solvents, split-flow configuration, steam injection, and heat recovery to determine integration feasibility and practicality prior to pilot plant testing*

Task 4

- Investigate opportunities to integrate solvent based CO_2 capture systems into existing and new Power Generation stations by:
  - ***simulating a new power plant with the improved CO_2 capture process***
  - ***identifying power plant waste heat sources suitable for use in CO_2 capture plant***

Task 5 & 6

- Complete unit cost analysis for amine unit as well as integrated power plant / capture unit
- Continued evaluation of operational issues such as corrosion, solvent degradation, and process control strategies.

Task 7 & 8

- Develop training package of the effective operation of a CO_2 capture module for pulverized coal power plants
- Investigate CO_2 product delivery and transport systems for optimization opportunities

Long term directions

- Process technologies
  - Column packings
  - Process integration issues
  - Process configulation issues
- Solvents technologies
  - Current solvents (FID, etc.)
  - Generic mixed solvents
  - New class of solvents
- Integrated Modeling and Simulation
  - Integrated modeling for power and CO2 productions
  - Comprehensive cost studies

New class of solvent technologies

- ***Formulated solvents (3 or more components, etc.)***
- ***Sterically hindered amines***
- ***Poly-structure amines***
- ***New molecular design solvents***
- ***Etc.***

ITC

Fundamental Research at ITC

www.uregina.ca

www.co2-research.ca

Research Program

- High Performance Structured Packings
- New Formulated Gas Treating Solvents
- Rate Enhancement Mechanisms & Reaction Kinetics of Mixed Amines
- Solvent Stability (Degradation) Studies
- Corrosion Control
- Co-generation Applications
- Process Integration

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Fundamental Research

- *Solvent formulation*
- *Solvent reaction & kinetics*
- *Thermodynamics*
- *Column hydrodynamics*
- *Solvent stability*
- *Mass transfer with chemical reactions*
- *Corrosion control and prevention*
- *Co-generation Applications*
- *Process Integration*
- *Intelligent monitoring, planning and control systems*

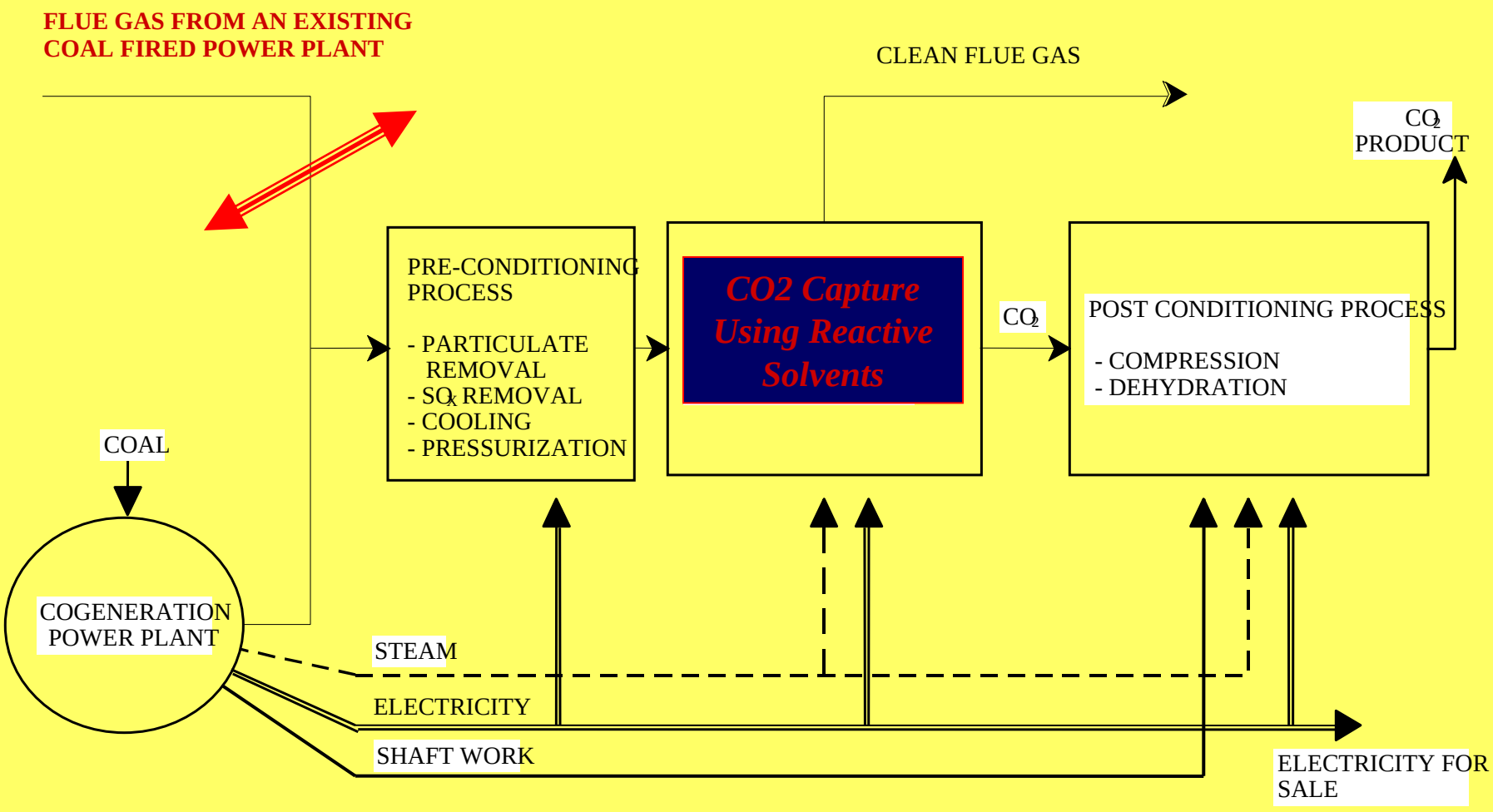
Why use reactive solvents for CO_2 capture?

- Theoretical issue
  - Mass transfer of CO_2 in liquid is 10 to 100 times faster
- Proven technology
  - Use in gas processing
- Available today !
- Cost ~ \$25 to \$50 per ton of CO_2 *(depending on situation and location)*
  - CO_2 for EOR ~ \$20 to \$100 per ton of CO_2
  - CO_2 trading ~ \$15 to \$35 per ton of CO_2

CO2 Life-cycle Analysis:
"Green oil" from CO2 for EOR application

	CO2 Emission: Life-cycle analysis
Primary oil production (reference case)	***1.0***
Secondary oil productions and Oil from Tar Sand Projects	***1.25 to 1.5***
"Green" Oil from CO2 – EOR applications	***0.5 to 0.75 (50% to 100% less CO2)***

Flexibility of Post-combustion Capture



Thank You !

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