Adsorption and Absorption Systems Overview

by

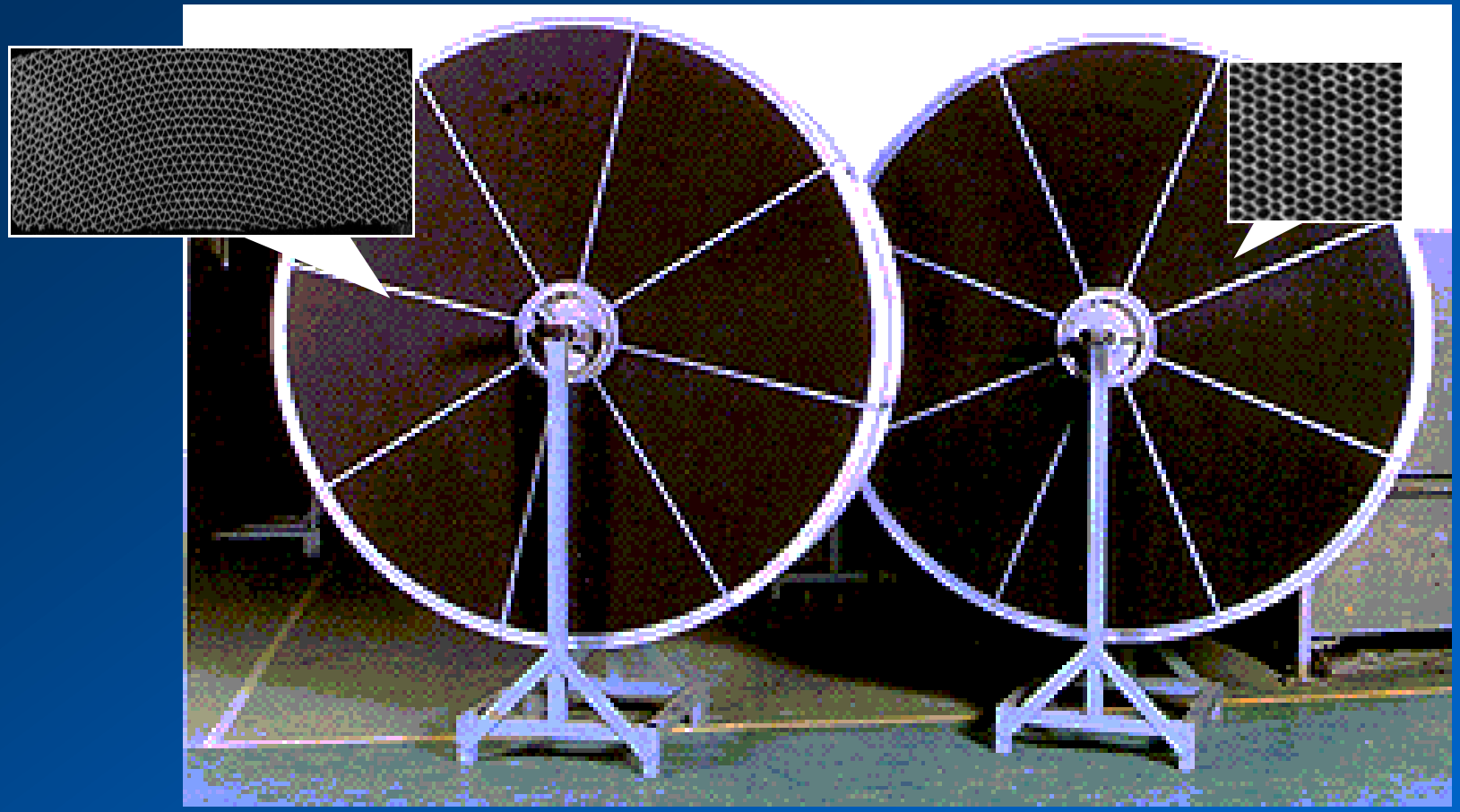
William M. Worek
Stony Brook University

May 12, 2014

ARPAe Meeting
Chicago, IL

Open-Cycle Solid Desiccant Systems

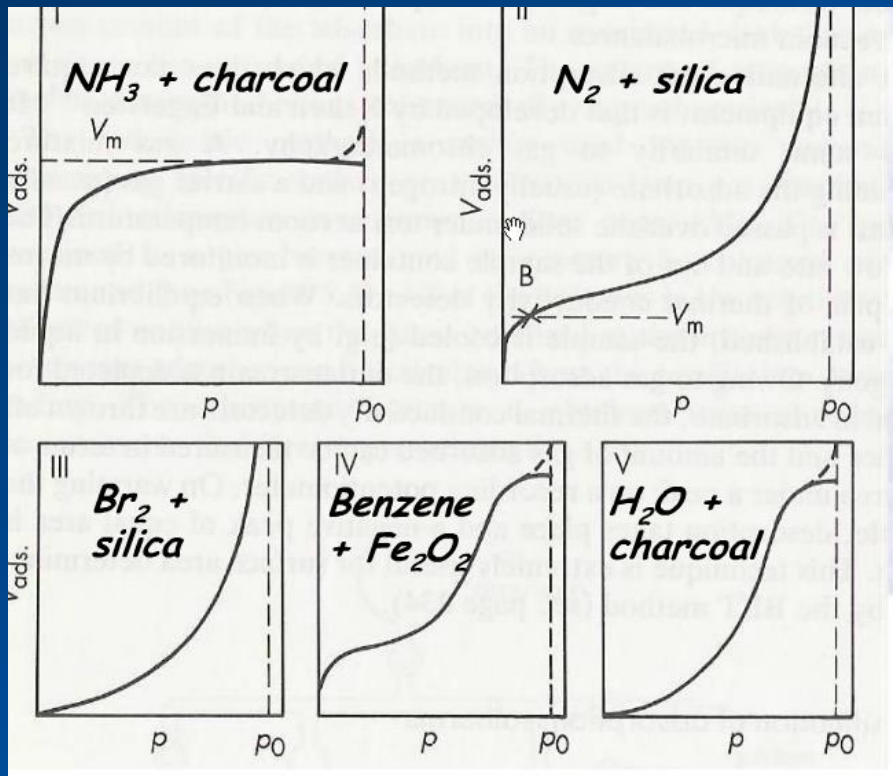
- Fixed Bed Systems – Not Used – Chemical Industry
- Rotary Systems
  - Rotor Manufacture
  - Rotor Cassette Design
- Can be used in Residential and Commercial Systems
- Largest Wheel 16 feet in diameter
  - Torque Issues
  - Sealing Issues
- Typical Depth 200 mm
- 50 cents/cfm
- 75 % of Rotor is Desiccant
- Maximum Desiccant Uptake 0.3 to 0.35

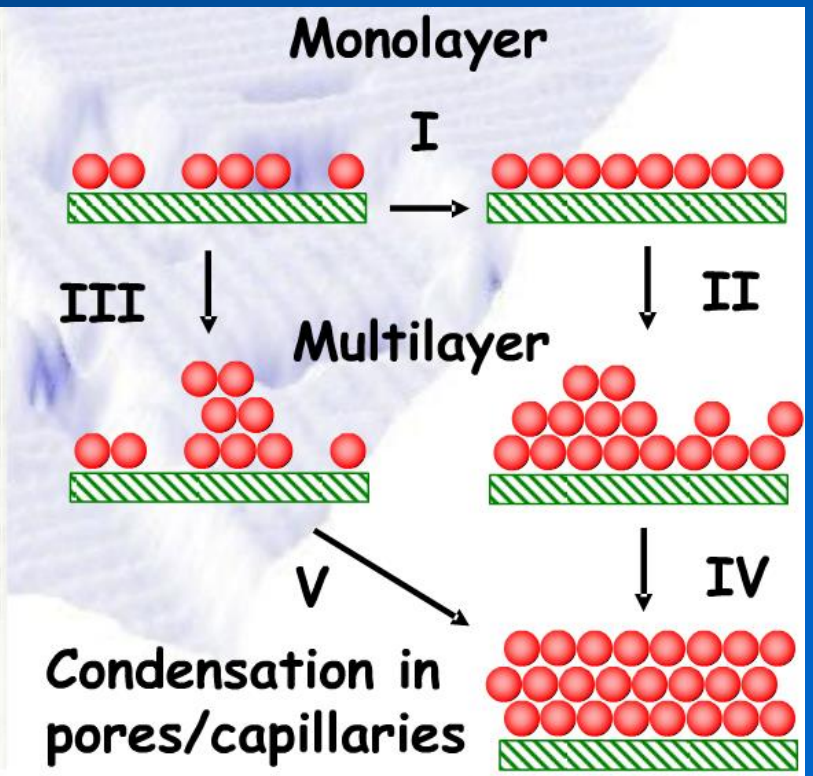


Rotor Manufacture-Typical Ranges

- Desiccant Material
  - 0.1 < Isotherm Shape Factor R < 10
  - 0.1 < Rotor Material Water Uptake < 0.3
  - 1 < Heat of Sorption/Latent Heat < 3
- Rotor Manufacture and Design
  - 5 < Rotor Density < 20 lb/ft^3
  - 4” < Rotor Depth < 8” (up to 16” typical of deeper drying rotors)
  - 1’ < Rotor Diameter < 16’
  - 600 ft^2/ft^3 < Heat and Mass Transfer Surface Area < 800 ft^2/ft^3

Classification of Isotherms
Brunauer, Emmett and Teller

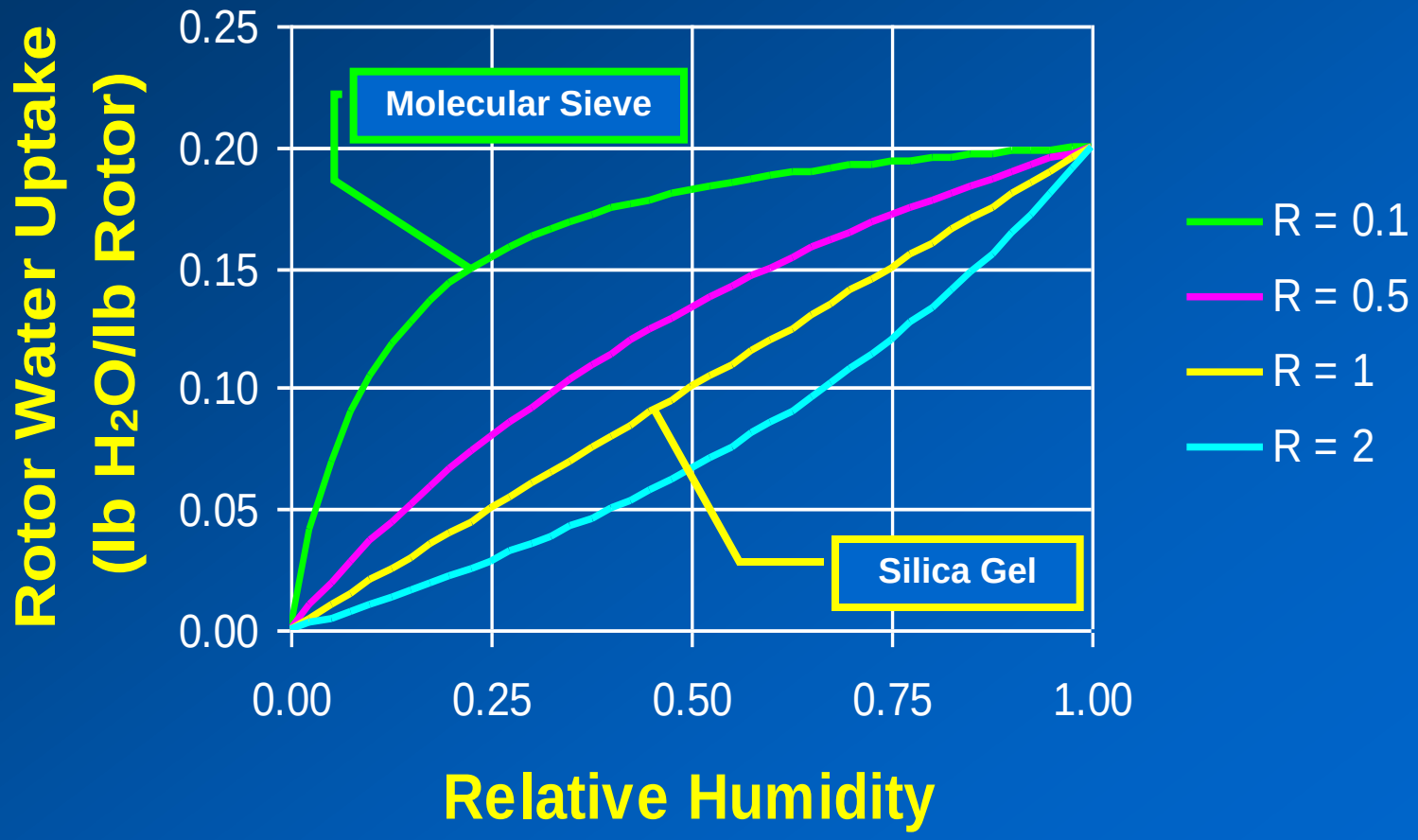


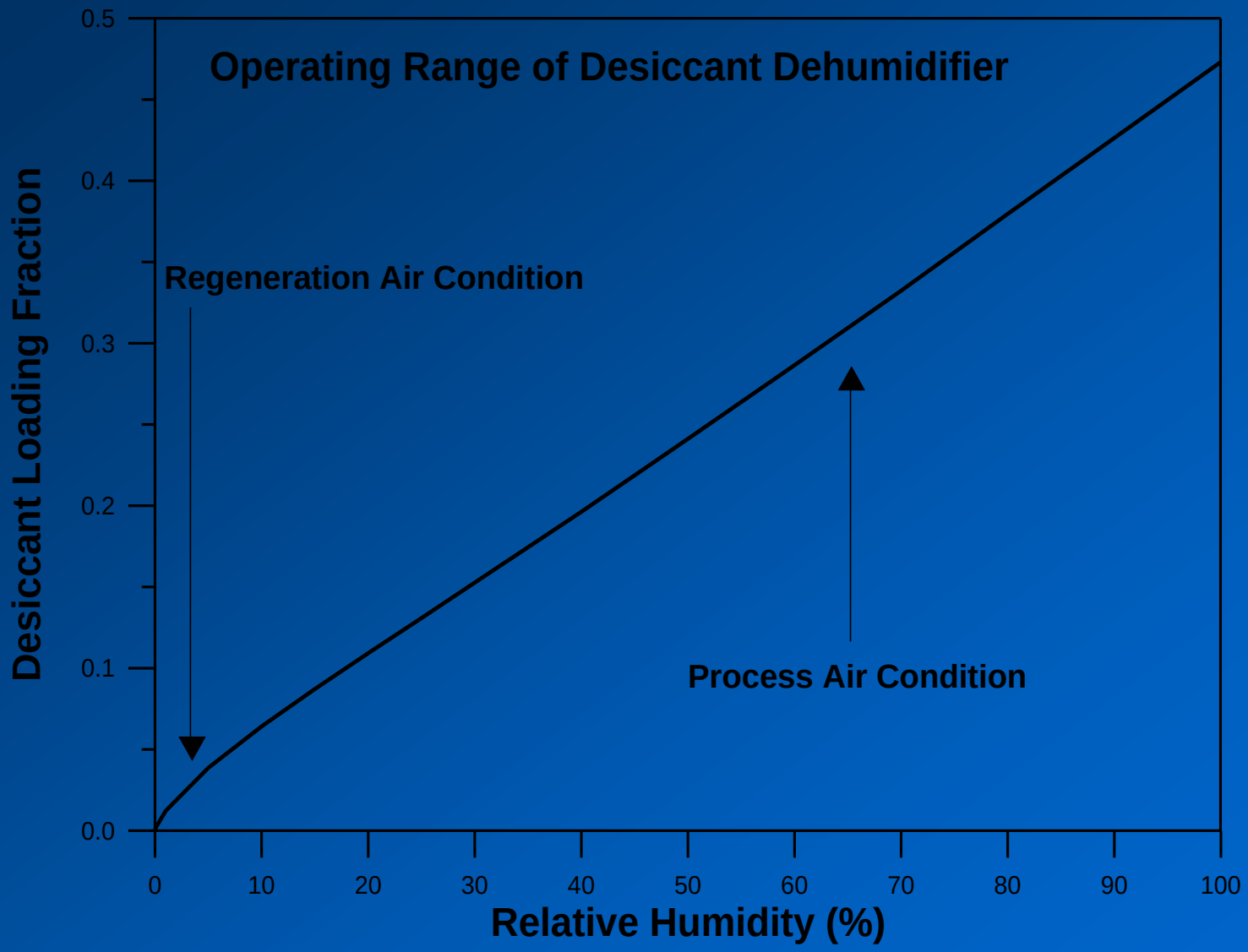


Apr 2004

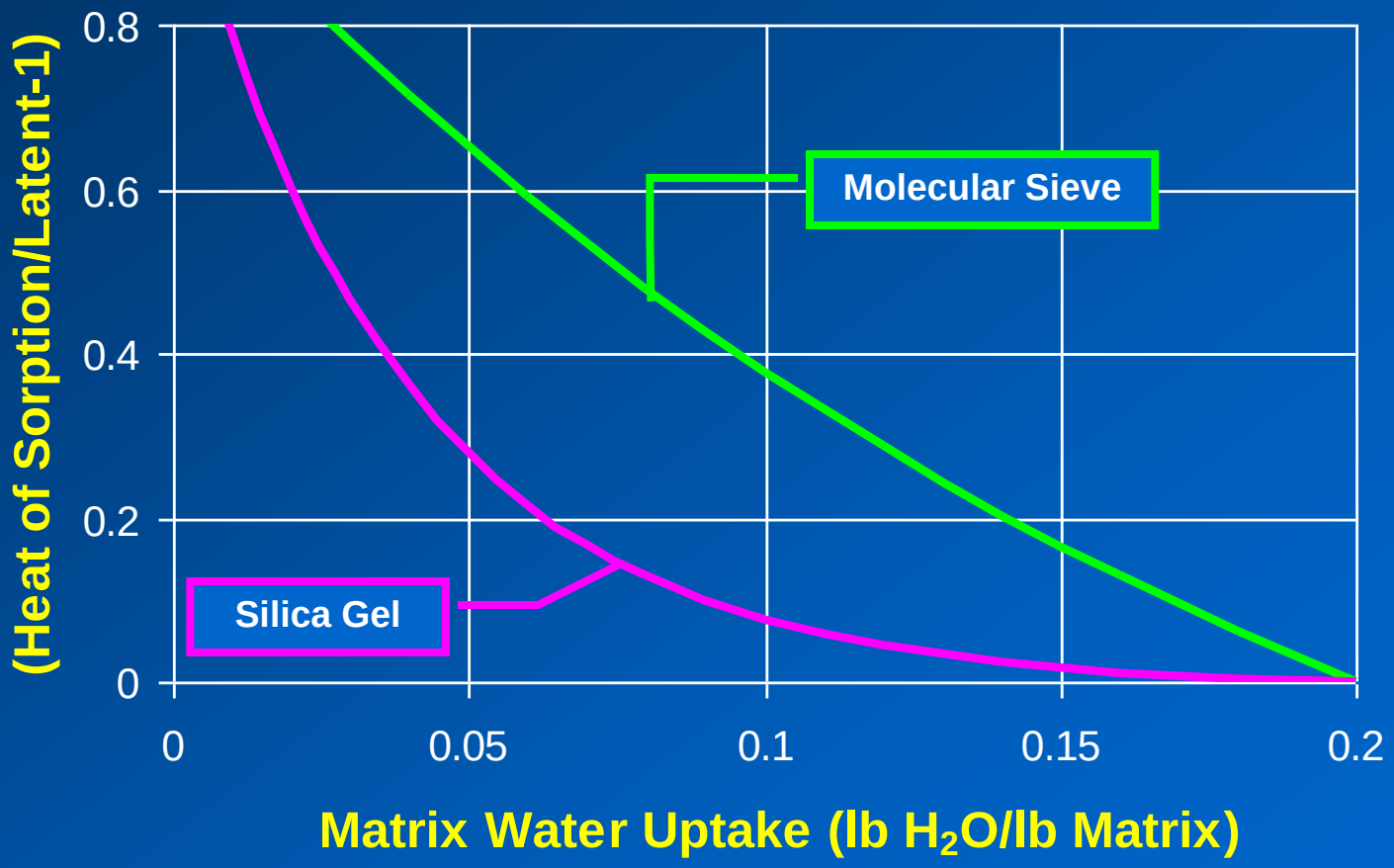
Dr Mark Osborne

Isotherm Shape




Operating Range of Desiccant Dehumidifier
Desiccant Loading Fraction
0.5
0.4
0.3
0.2
0.1
0.0
Regeneration Air Condition
Process Air Condition
0
10
20
30
40
50
60
70
80
90
100
Relative Humidity (%)

Heat of Sorption

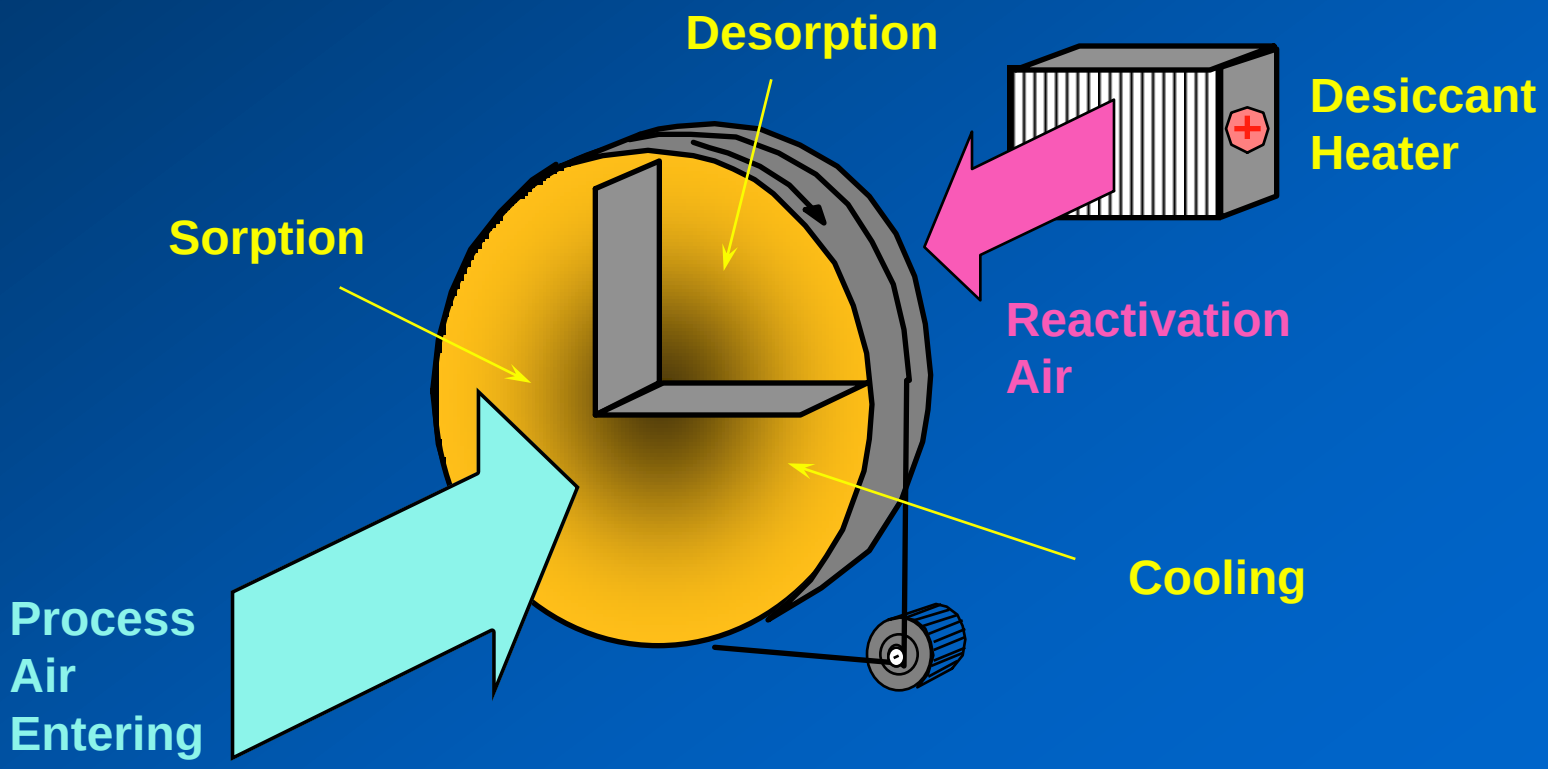


Rotor System - Typical Values

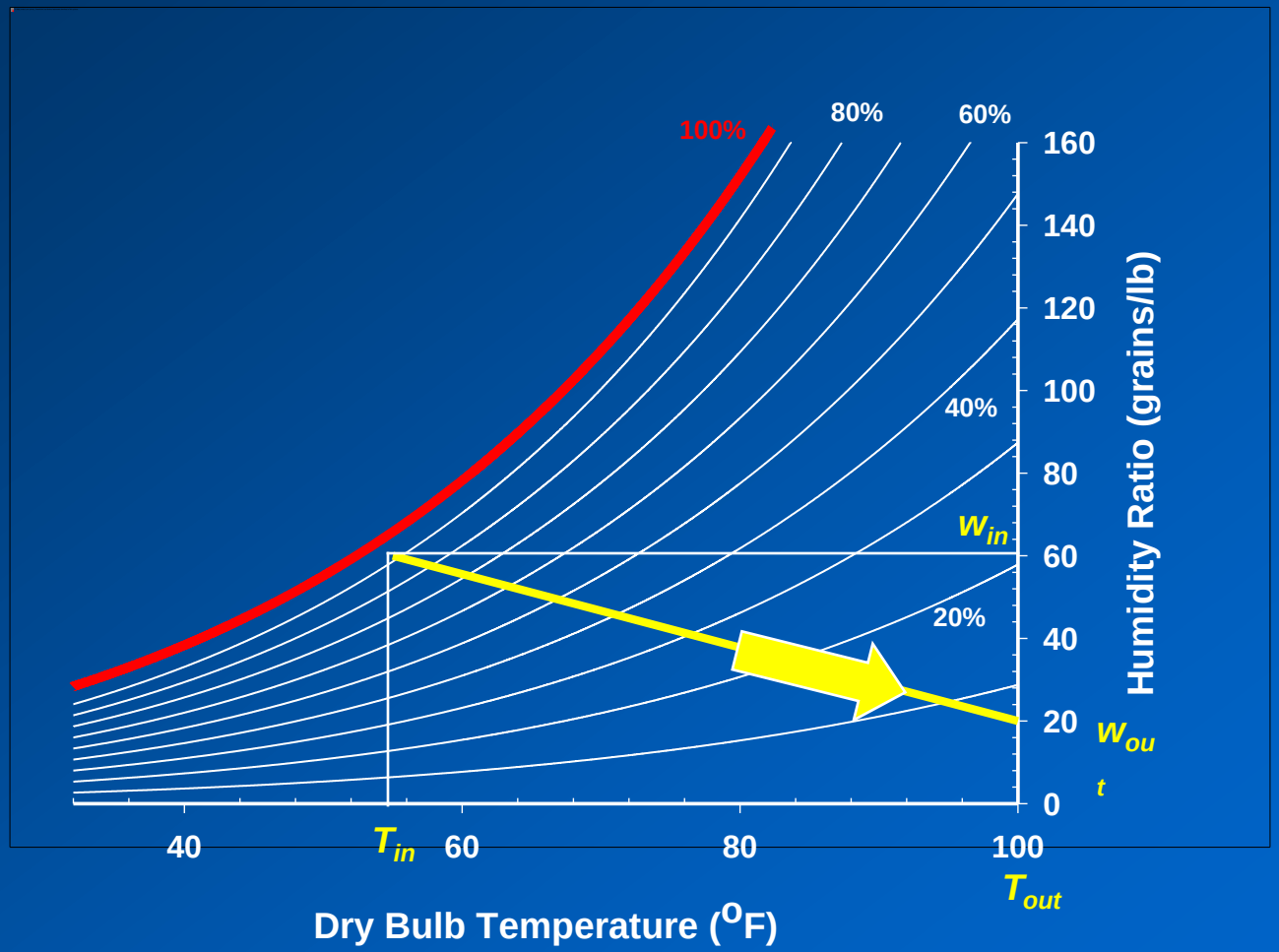
- Rotor Cassette Design
  - 90^{o} < Regeneration Angle < 180^{o}
  - 5 rph < Wheel Rotational Speed < 50 rph
- Component Operation
  - 200 fpm < Air Face Velocity < 800 fpm
  - 200^{o}F < Regeneration Temperature < 350^{o}F
  - 5^{o} < Purge Angle < 10^{o}

Desiccant Wheel

90º Regeneration



Typical Adsorption Psychrometric Process



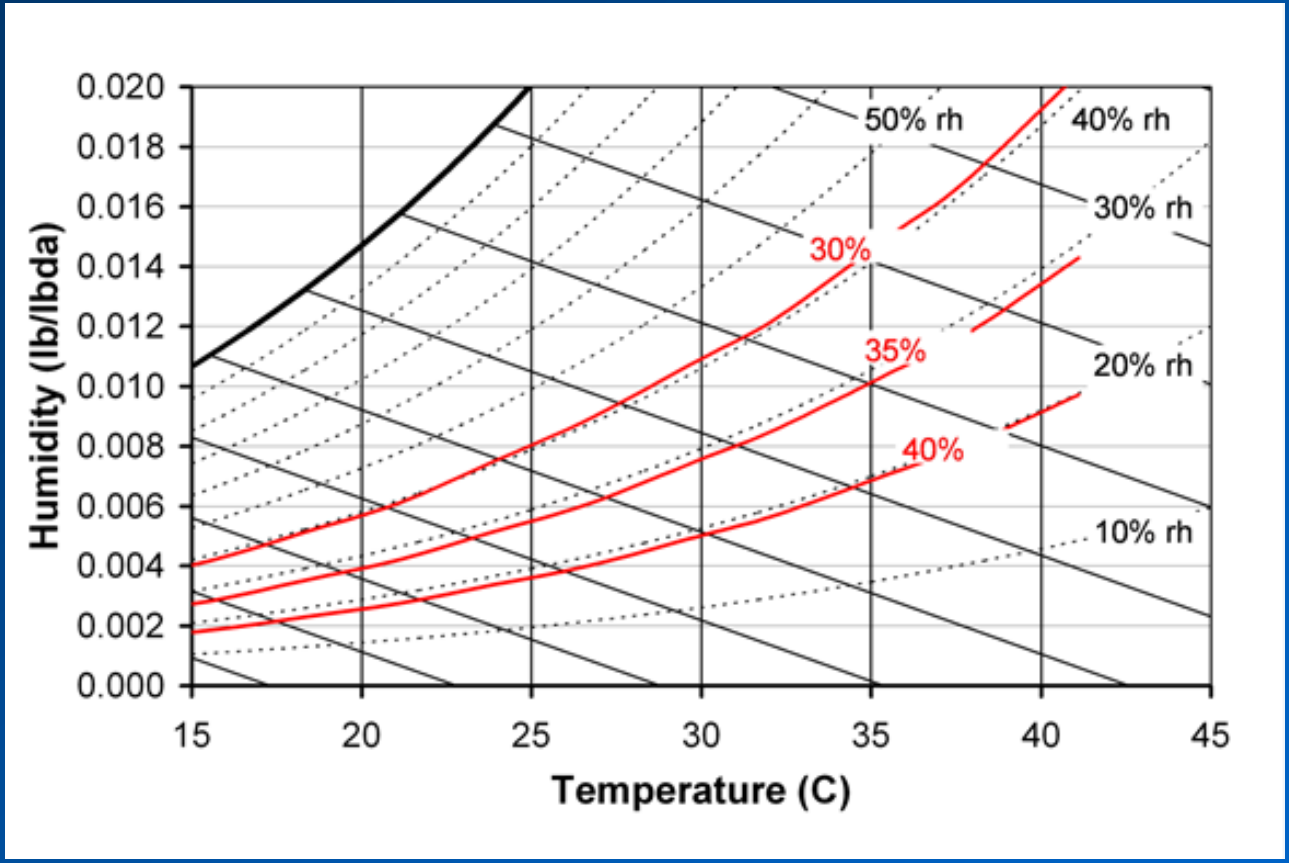
Summary of Findings

• Face Velocity	**Higher Face Velocity**	↓ **grains/lb**
	Higher Face Velocity	↓ **Drying Capacity**
	(constant scfm)	
	Higher Face Velocity	↑ **Drying Capacity**
	(constant rotor diameter)	
• Heat of Sorption	**Higher Heat of Sorption**	↓ **grains/lb**
• Rotational Speed	**Best Speed 10 to 20 rph except for low density matrix**	
• Regeneration T	**Higher Regeneration Temperature**	↑ **grains/lb**
• Isotherm Shape	**R ≈ 0.1 High Regeneration Temperature**	
	R ≈ 0.5 to 1 Lower Regeneration Temperature	
• Matrix Water Uptake	**Higher Moisture Uptake**	↑ **grains/lb**
• Wheel Thickness	**Thicker Wheels**	↑ **grains/lb**
	Thicker Wheels	↑ **Pressure Drop**

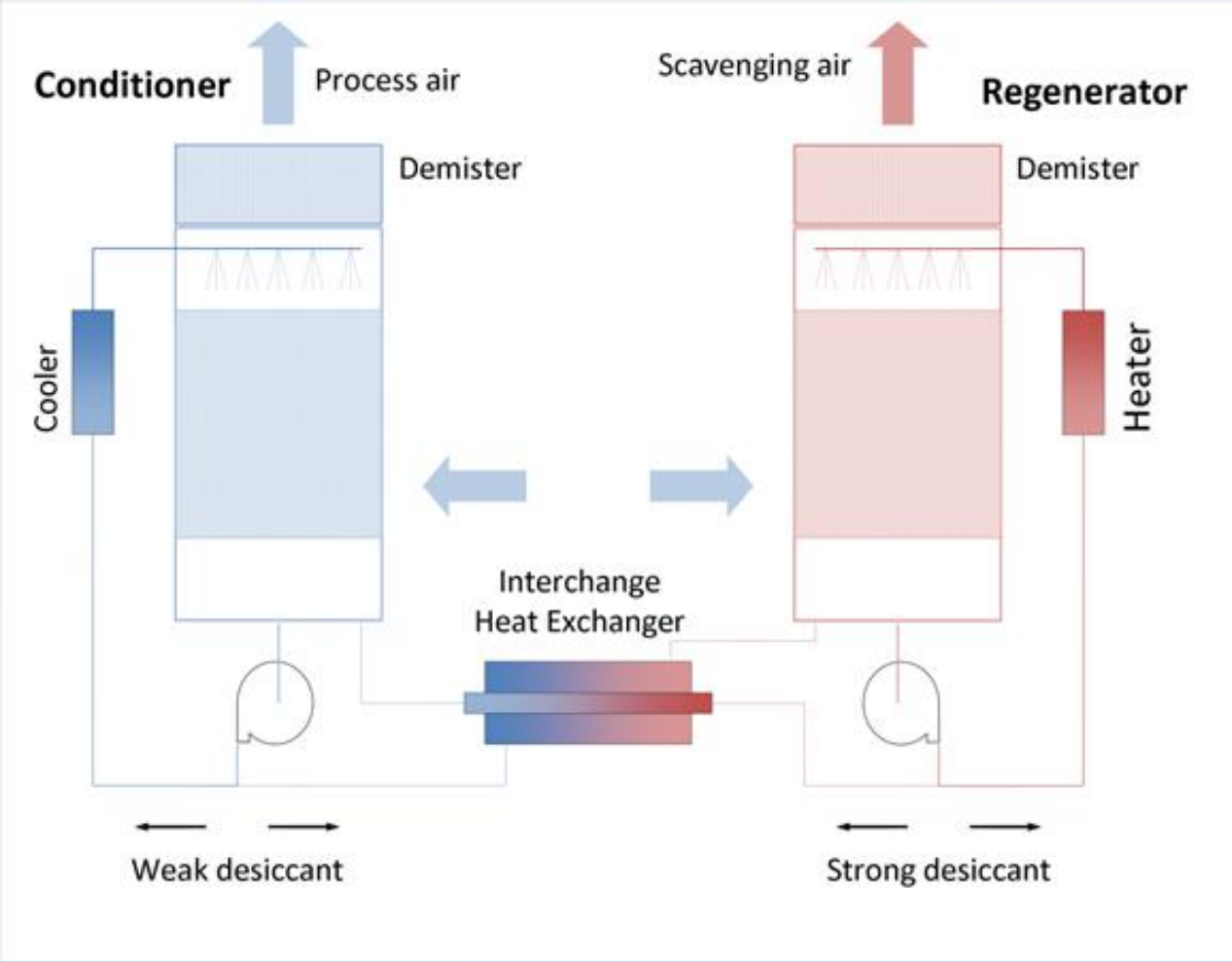
OPEN-CYCLE LIQUID DESICCANT SYSTEMS

Implementation

- Liquid Desiccant Systems are Typically Used in Industrial Applications
- Advantage Can Have Multiple Absorbers
- Biocidal
- Most Common Liquid Desiccants are
  - Lithium-Chloride H_2O
    - Better Absorber
    - More Expensive $2.80 per pound - $135 ton - hour
  - Calcium-Chloride H_2O
    - Little Poorer than LiCl
    - Cheaper than LiCl – 0.1 the cost of LiCl
  - Sometimes a 50/50 mixture is used to lower cost
  - Glycols Can Be Used – Problem with Carryover
    - Ok in Industrial Systems



LiCl-Water Equilibrium for Different Concentrations


Conditioner
Process air
Scavenging air
Regenerator
Demister
Demister
Cooler
Heater
Interchange
Heat Exchanger
Weak desiccant
Strong desiccant

"Status of Liquid Desiccant Technologies and Systems", Worek and Lowenstein

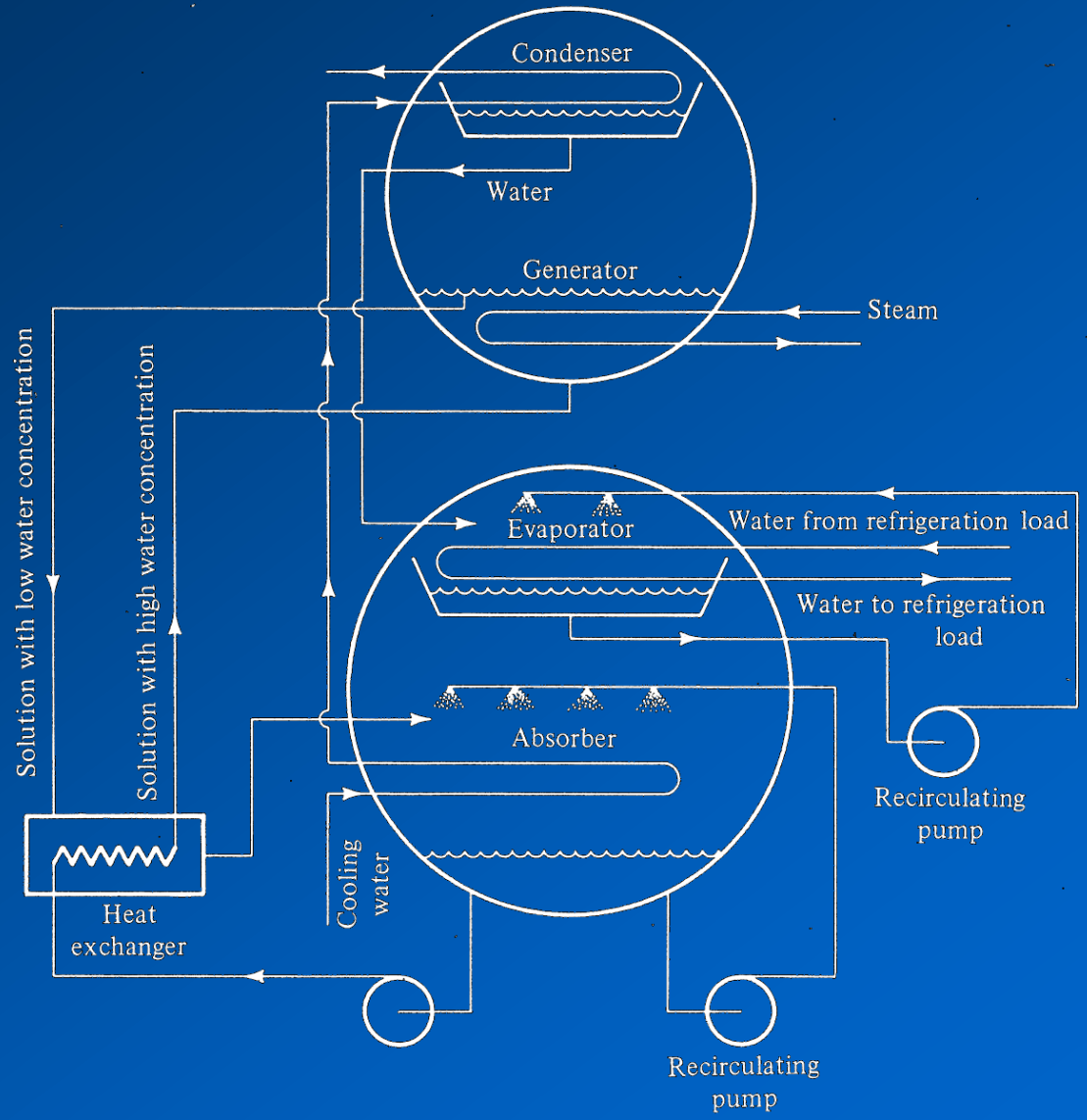
Book citation is:

Desiccant-Assisted Cooling, Fundamentals and Applications
Nobrega and Brum, Editors
Springer, 2014

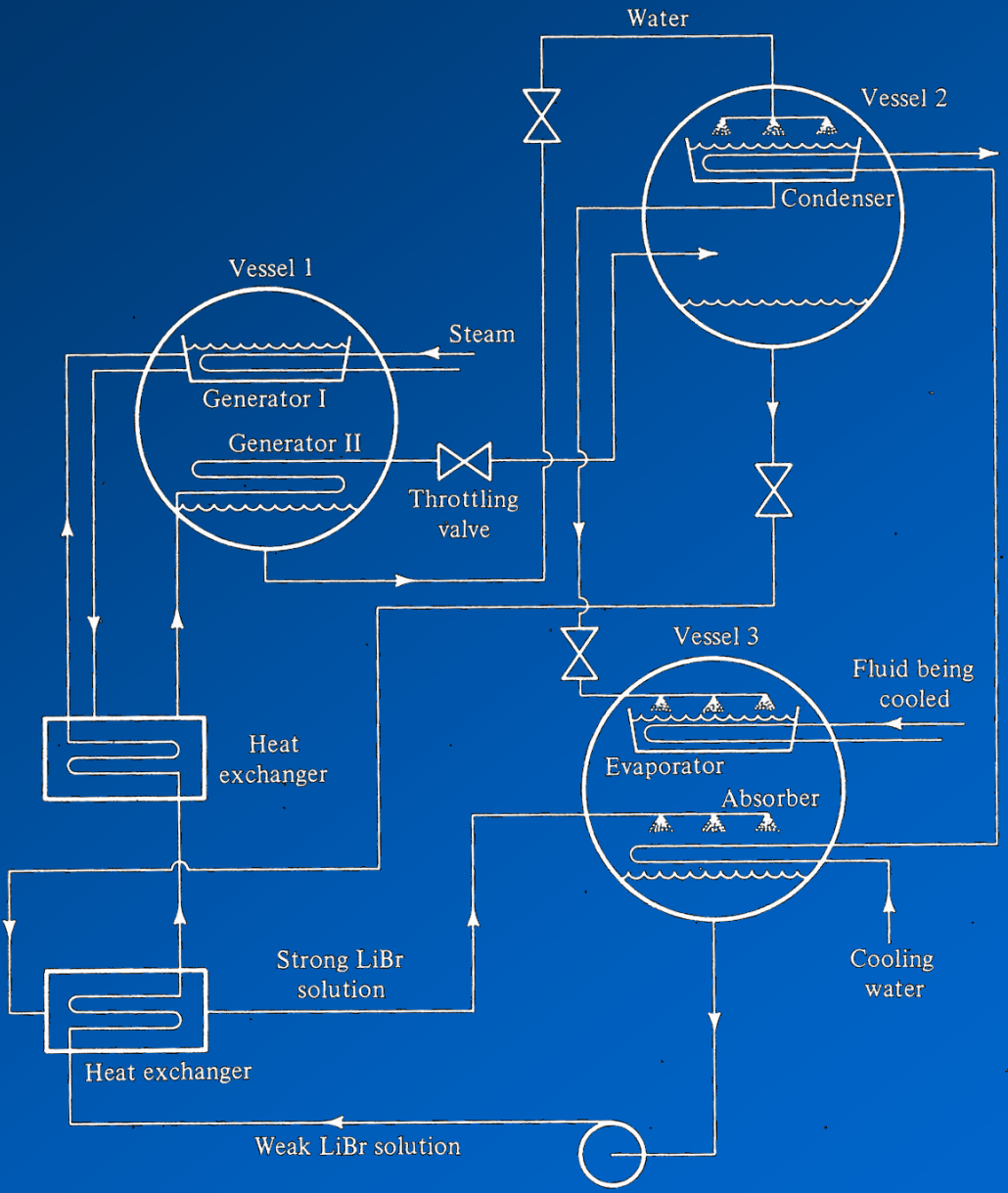
Closed-Cycle Systems

Commercial

Single-Effect Absorption Unit Arrangement

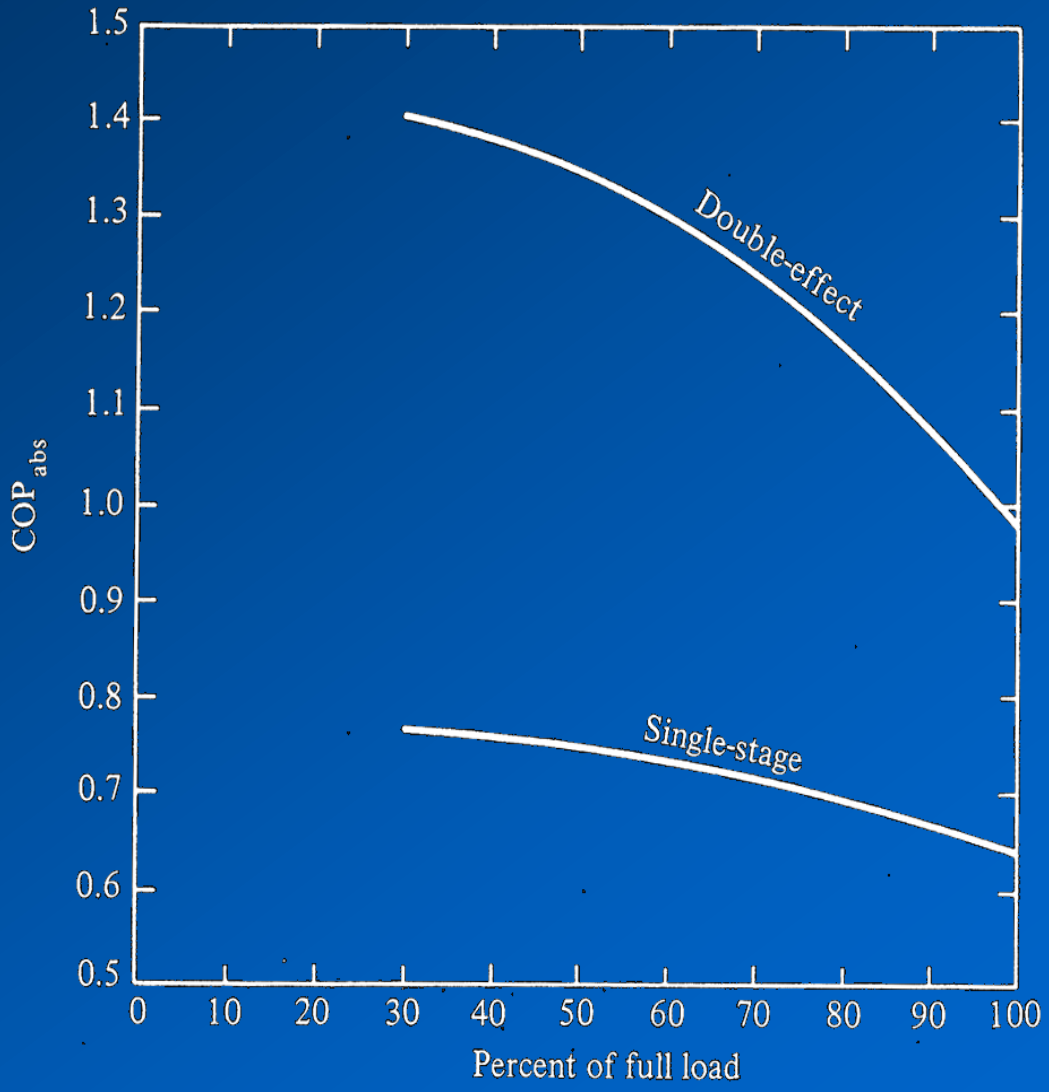


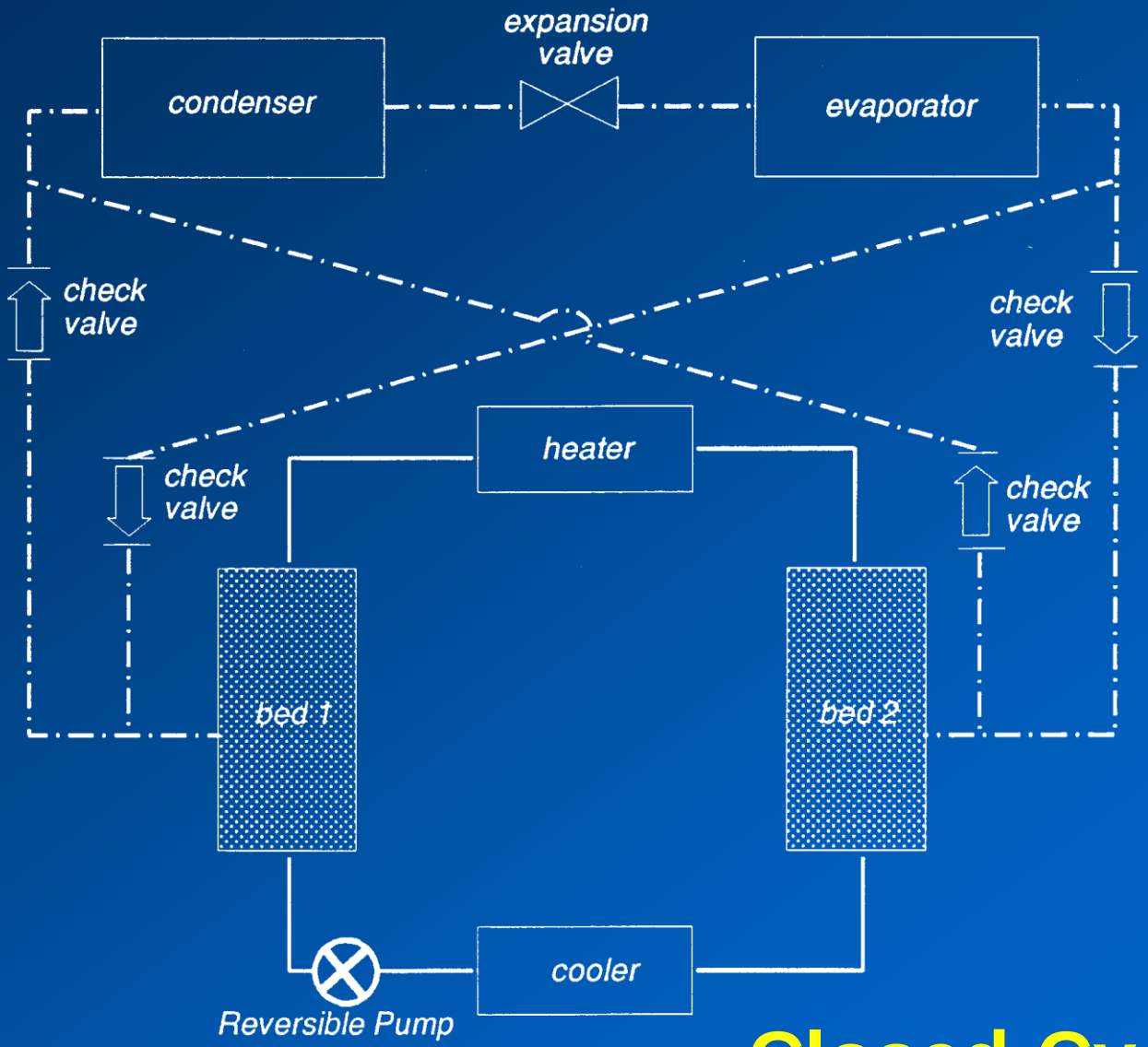
Double-effect System Schematic



System Performance Comparison

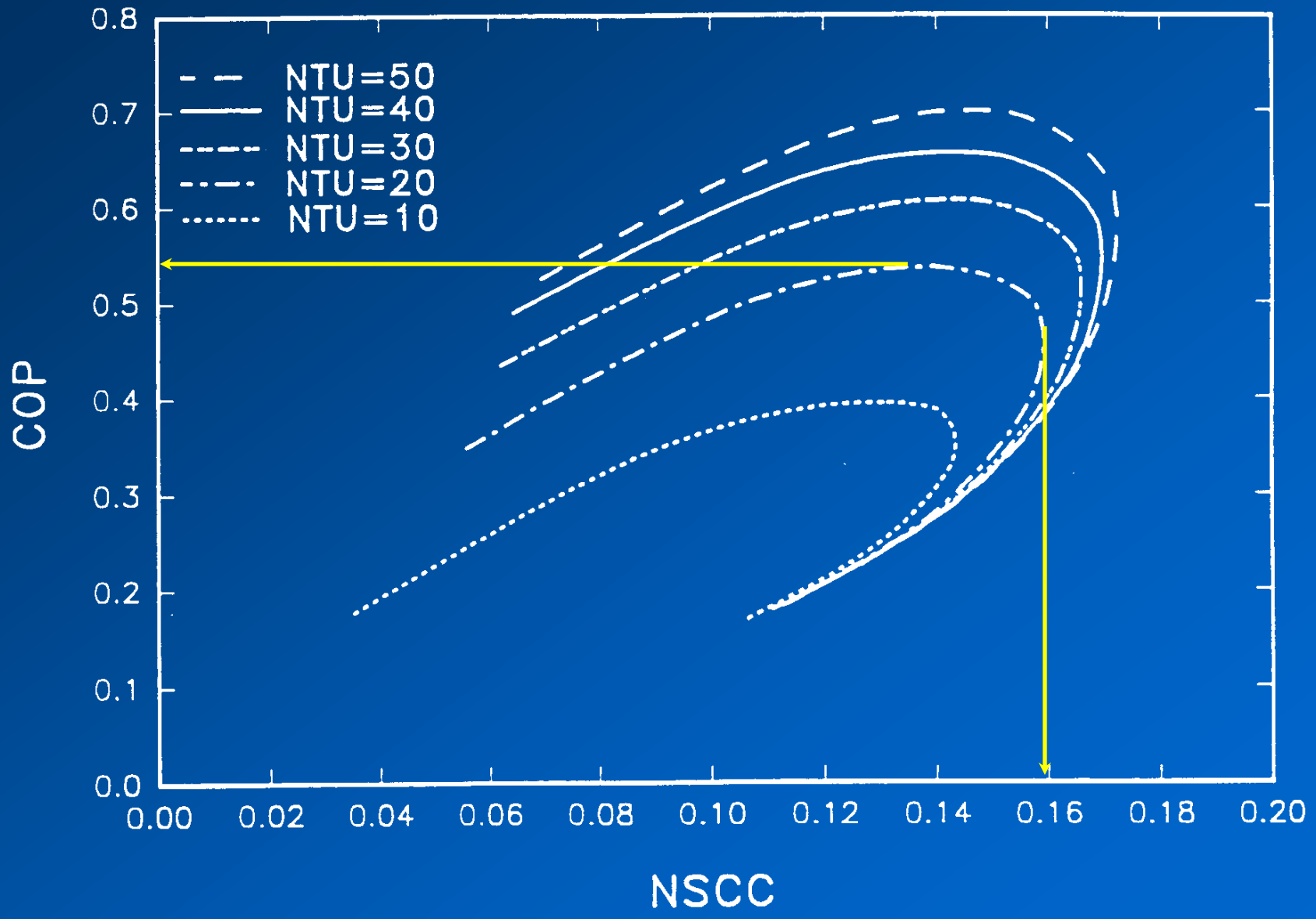
Single-effect versus Double-effect





Closed-Cycle Thermally-Activated Heat Pump

Optimum COP or Capacity



How to Improve System Performance and Capacity

- Material Research
  - Higher Adsorbate Uptake per Unit Weight of Sorbent
  - Lower Heat of Sorption
  - Earth Friendly and Non Toxic Material
- System Research
  - Innovative System Designs
  - Hybrid Integrated Systems