Desiccant Cooling and Dehumidification

HVAC Technology for 1990s

HVAC: Heating, Ventilation, and Air Conditioning

Desiccant Cooling Group
Solar Energy Research Institute
Golden, Colorado

Table of Contents

- Background and Fundamentals
- SERI Desiccant Research
- Status of Desiccant Technology
- Future Research Trusts

Challenges Facing HVAC Industry in 1990's

- Reduction of CFCs
- Indoor air quality
- Improved comfort and environmental control
- Increased ventilation requirements
- Increased efficiency standards
- Rising peak-demand charges

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Desiccant Cooling and Dehumidification

An Alternative for Space Conditioning

Desiccant cooling and dehumidification technology has the potential to solve the problems of the HVAC industry faced in 1990's for space conditioning.

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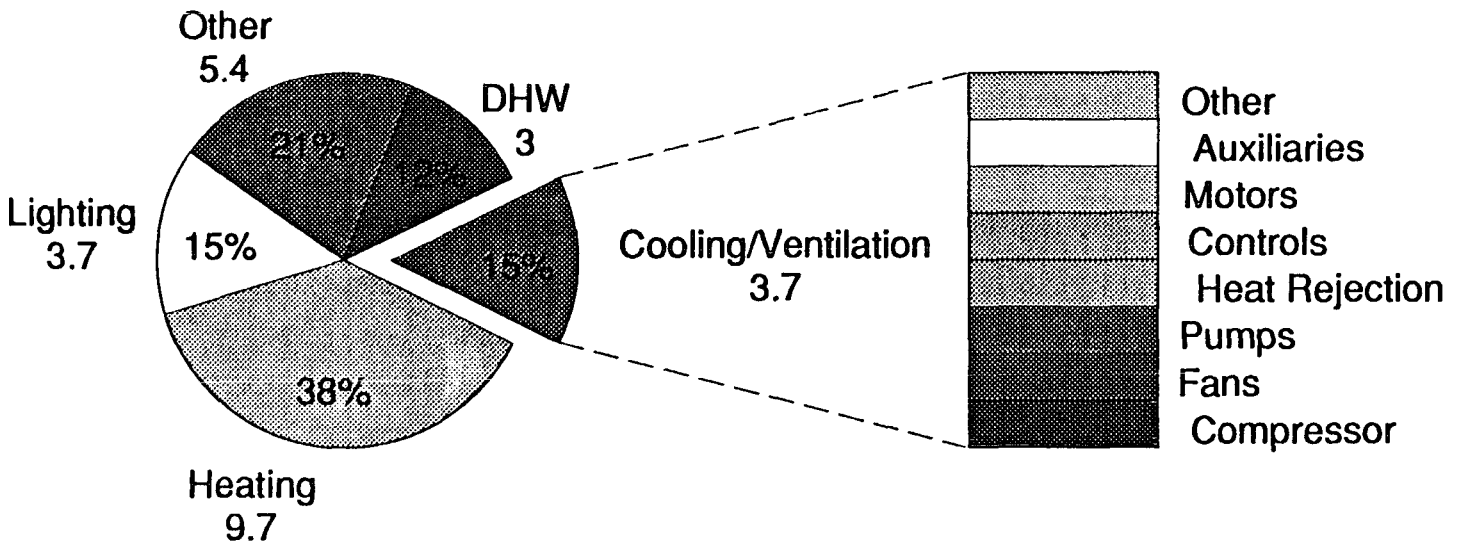
Desiccant Cooling and Dehumidification
Primary Energy End Use Sector/Subsector



1985 Primary Energy Use for all Buildings in Quads

Energy Users for Cooling/Ventilation

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Air-Conditioning Basic Functions

- Moisture Control..... Dehumidification
- Temperature Control..... Sensible Cooling

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Desiccants are materials that remove moisture and pollutants from fluids

Solid Desiccants	Liquid Desiccants
Silica gel	Glycerol
Activated carbon	Triethylene glycol
Molecular sieves	Lithium chloride solution
Activated alumina	Lithium bromide solution
Polymers	Polymers
Lithium chloride salt	
Calcium chloride salt	

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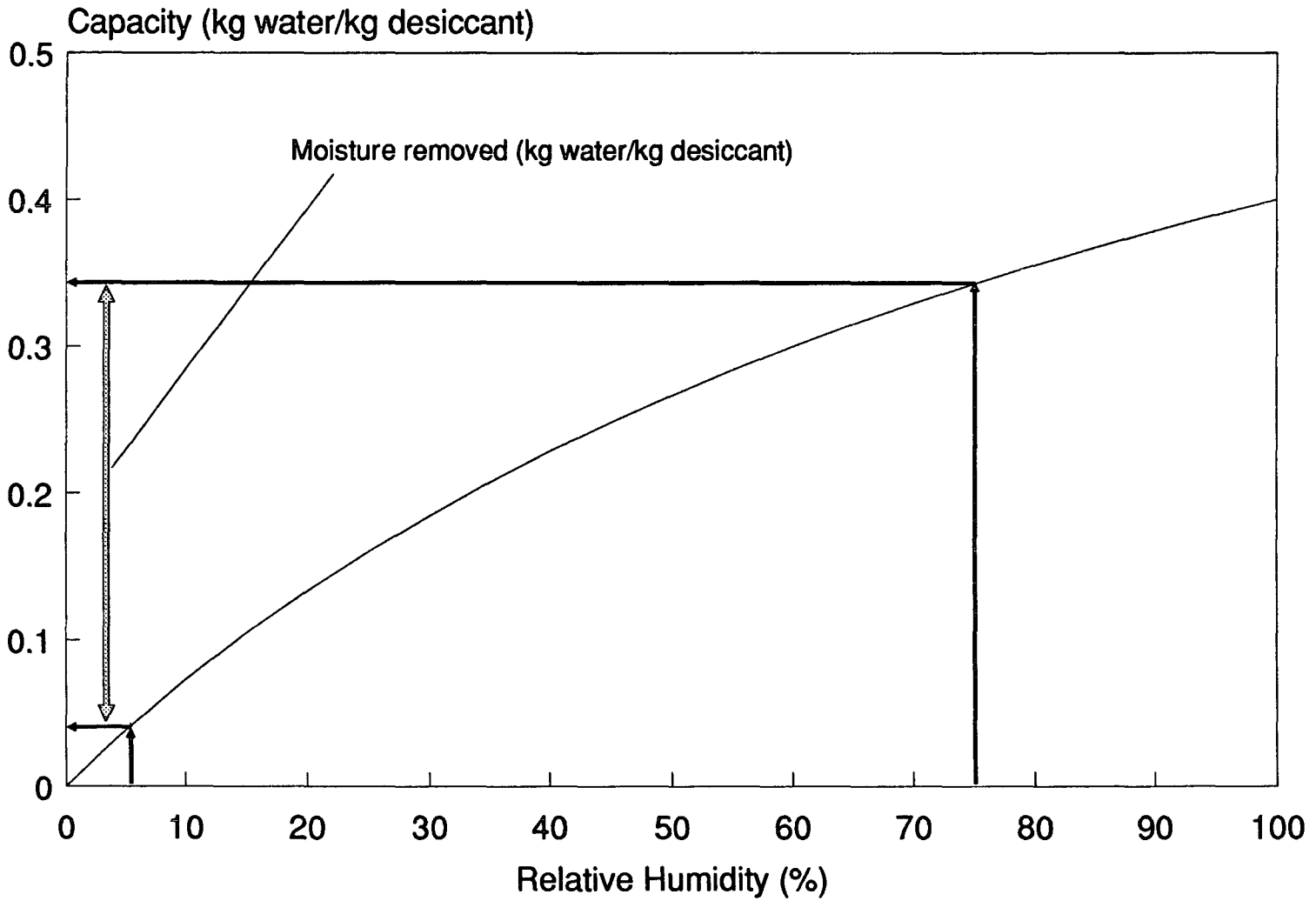
Desiccants remove miosture from air



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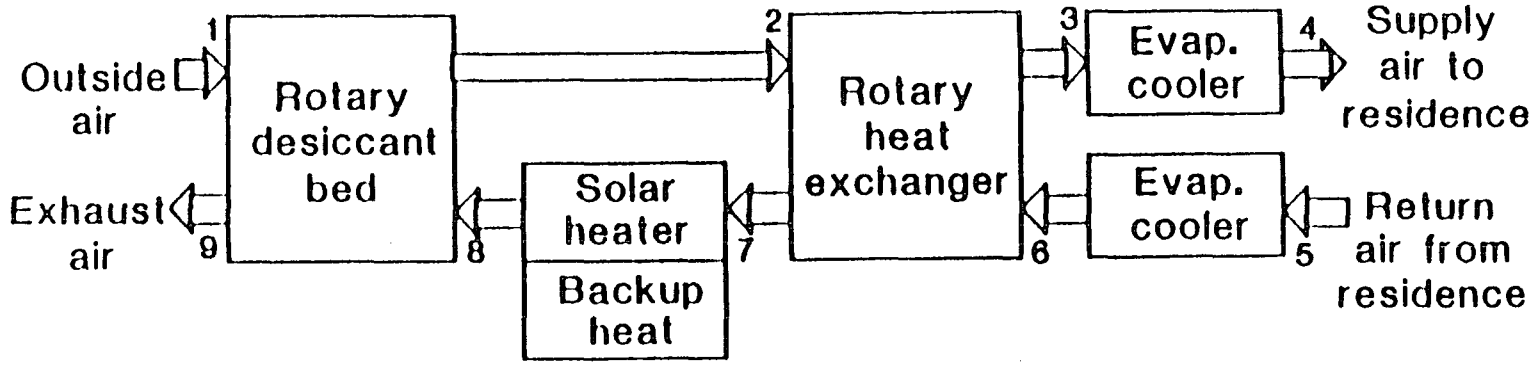
Desiccant Cooling and Dehumidification

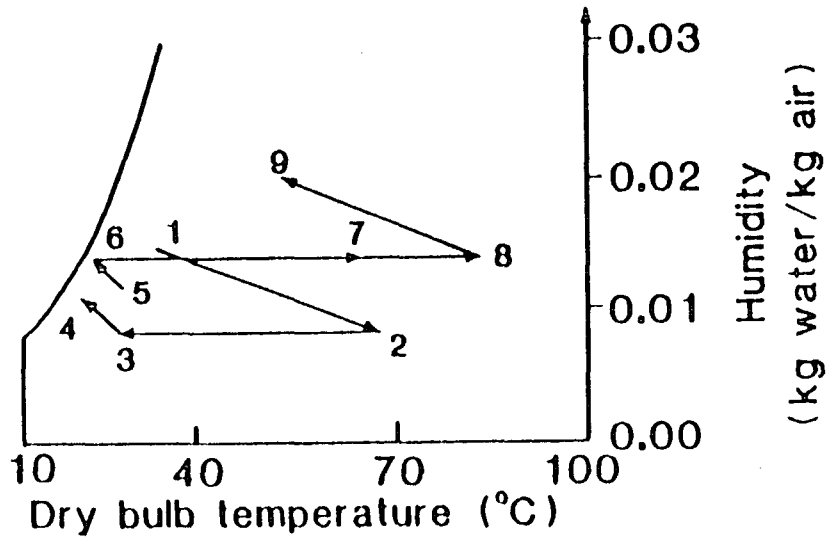
How Does it Work?

- Air dehumidification by desiccant dehumidifier
- Subsequent air cooling by sensible air coolers
- Reactivation of desiccant by hot air from solar, waste heat, natural gas, or off-peak electricity

(Separate handling of latent and sensible loads)

Ventilation Cycle Desiccant Cooling System





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Best Circumstances for Use of Desiccant Cooling and Dehumidification

- Need for humidity control
- Economic benefits to low humidity
- High latent load vs. sensible load
- Low cost thermal energy vs. high cost electric energy
- Need for dry cooling coils and ductwork

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Desiccant Cooling Markets

- Supermarkets
- Restaurants/fast foods
- Office buildings
- Hospitals nursing/homes
- Swimming pools
- Health clubs/gyms

Desiccant Cooling Research
at
Solar Energy Research Institute

SERI's Desiccant Capabilities

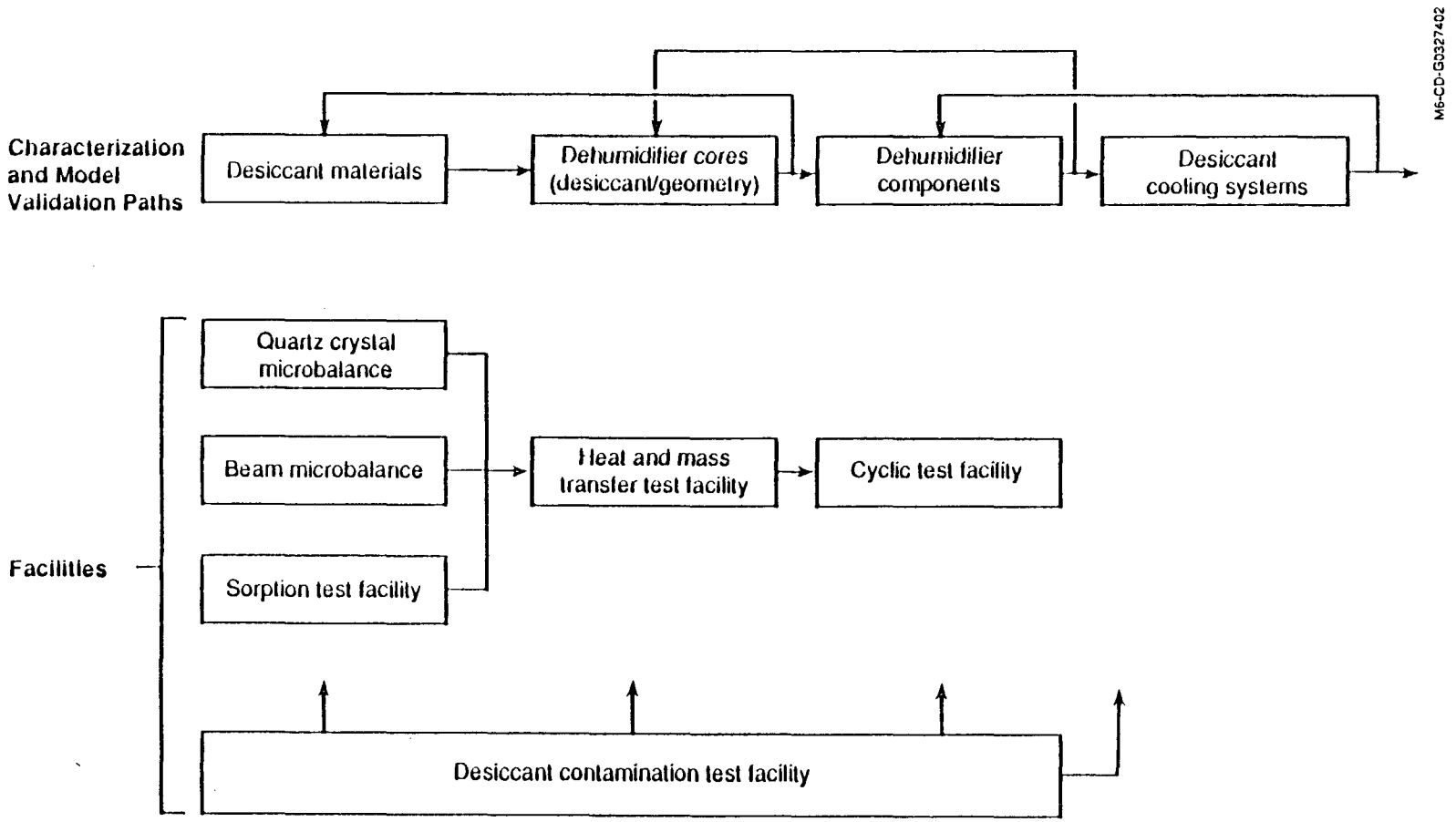
- Experienced staff
- Unique test facilities
- Analytical tools
- Development and characterization
- Knowledge of national/international state-of-the-art desiccant and HVAC technology and industry

SERI's Desiccant Capabilities

Unique Test Facilities

- Materials
  - Quartz Crystal Microbalance
  - Beam Microbalance
  - Sorption Test Facility
- Matrices
  - Heat and Mass Transfer Test Facility
- Components
  - Cyclic Test Facility
- Durability/Pollutant Removal
  - Desiccant Contamination Test Facility

SERI Desiccant Cooling Test Facilities and Research



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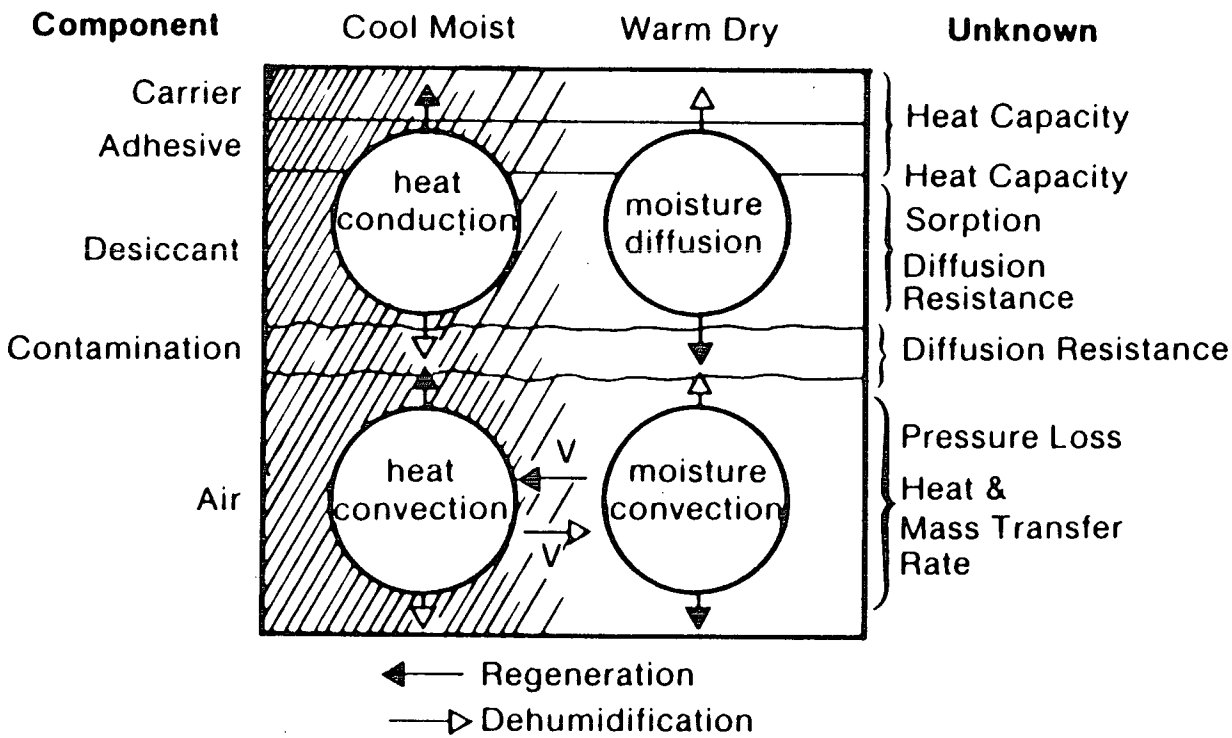
Combined Heat and Mass Transfer Processes in a Dehumidifier



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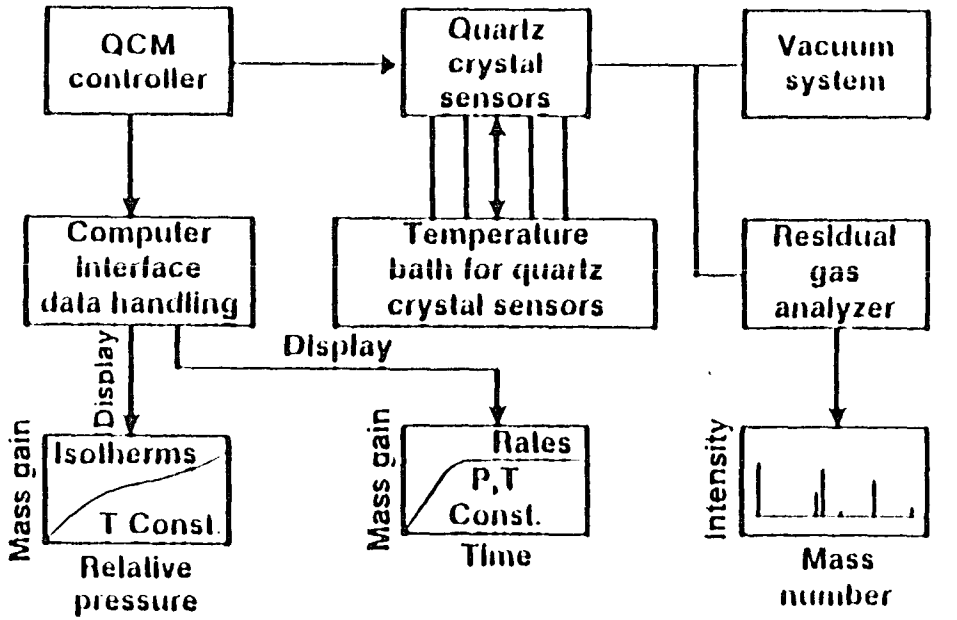
Principal Components of a Quartz Crystal Microbalance Sorption Apparatus



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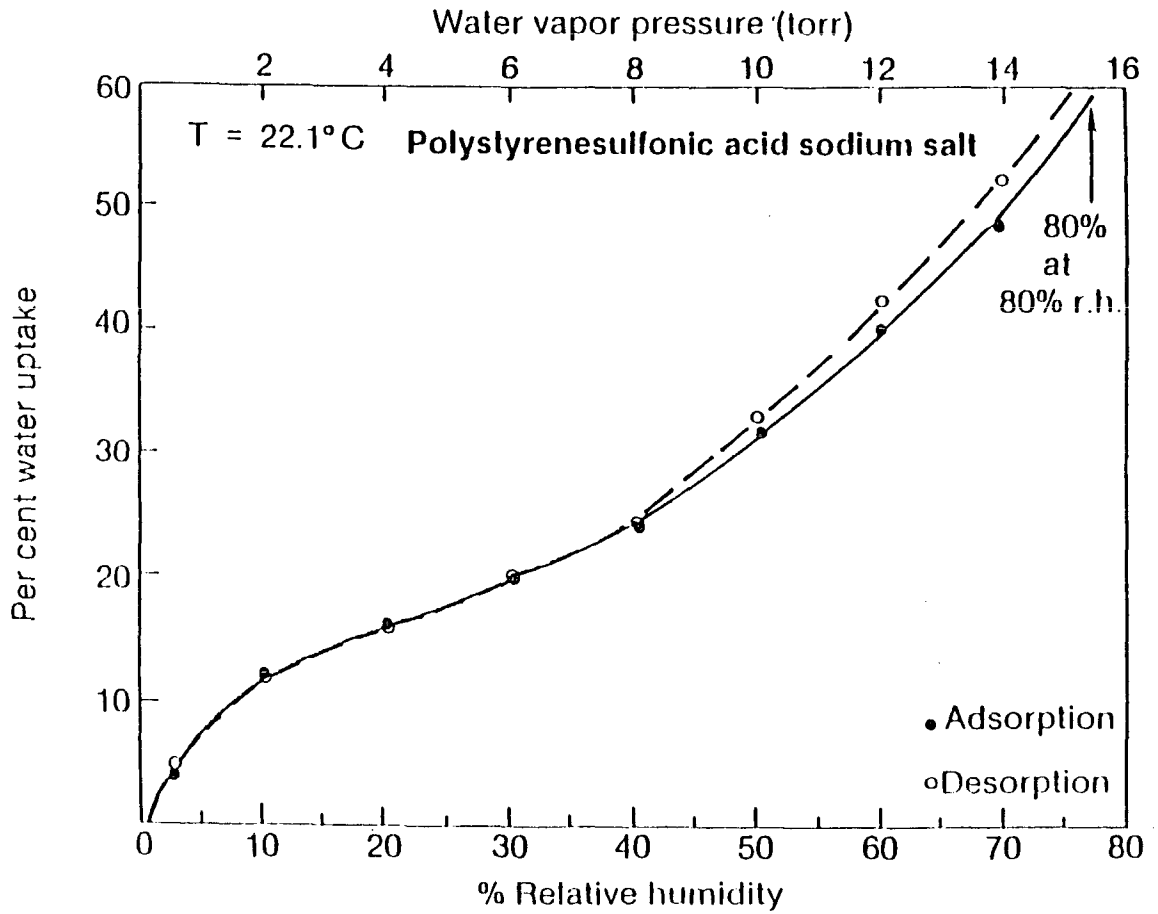
Typical Results from Quartz Crystal Microbalance



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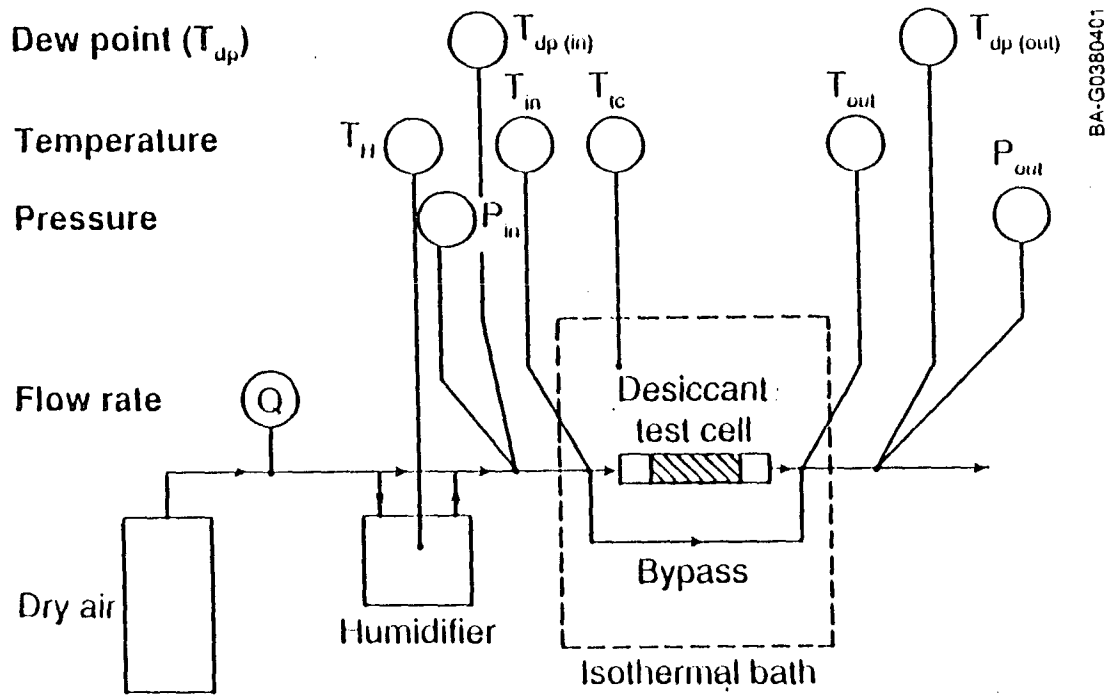
Desiccant Sorption Test Facility



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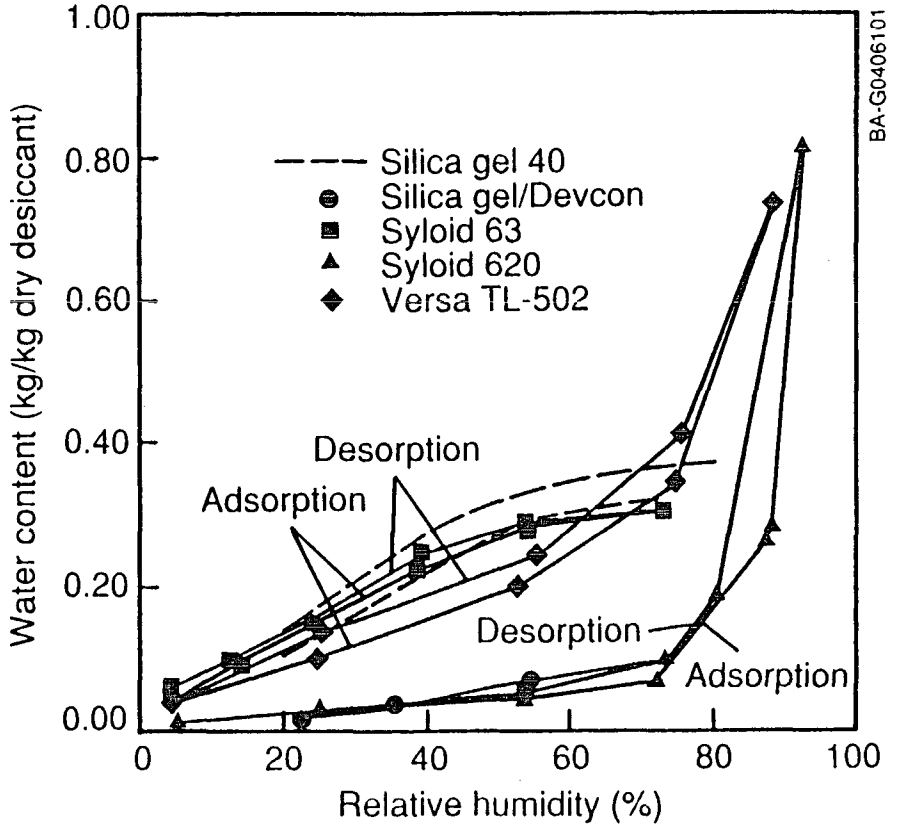
Typical Results of the Sorption Test Facility, Adsorption/Desorption Equilibrium Capacity of Several Desiccants at 30°C



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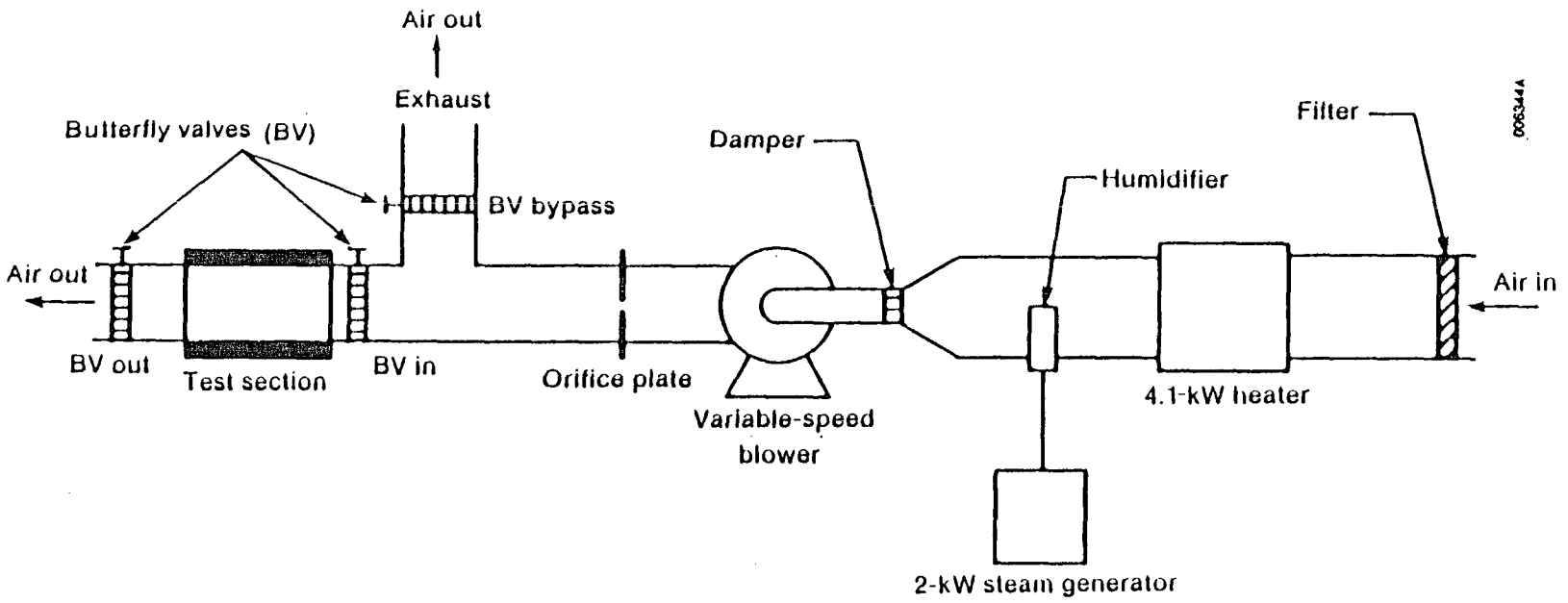
Desiccant Heat and Mass Transfer Test Facility



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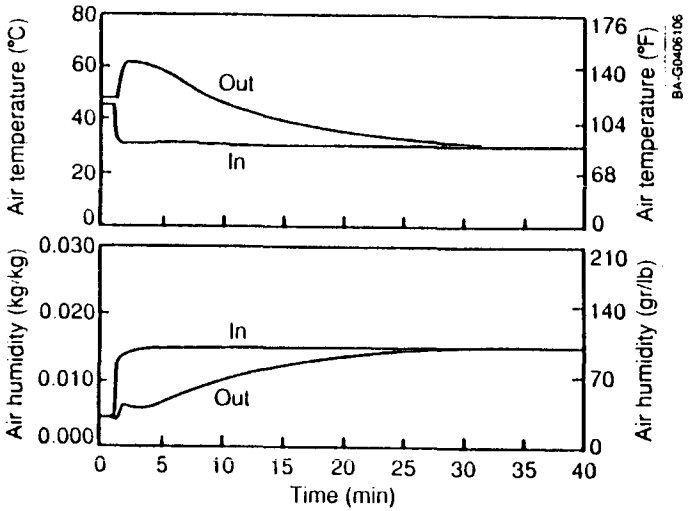
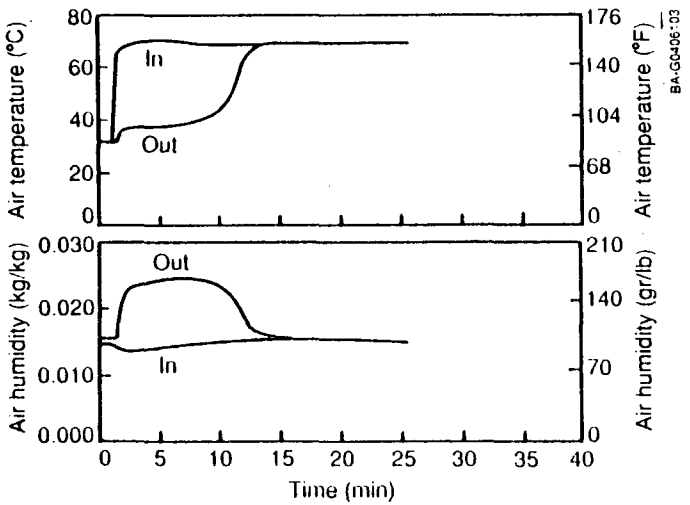
Results of Transient Response Experiment for the Silica Gel/Corrugated Test Matrix (adsorption run)



Results of Transient Response Experiment for the Silica Gel/Corrugated Test Matrix (desorption run)



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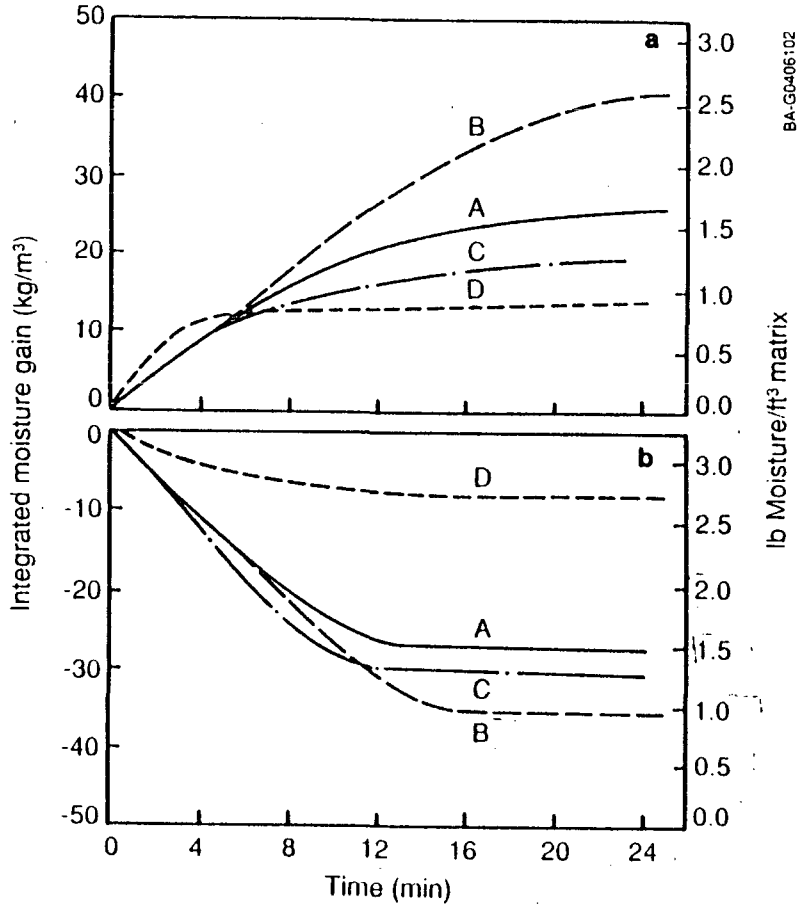
Transient Dehumidification Capacity of Four Test Matrices; a: Adsorption, b: Desorption



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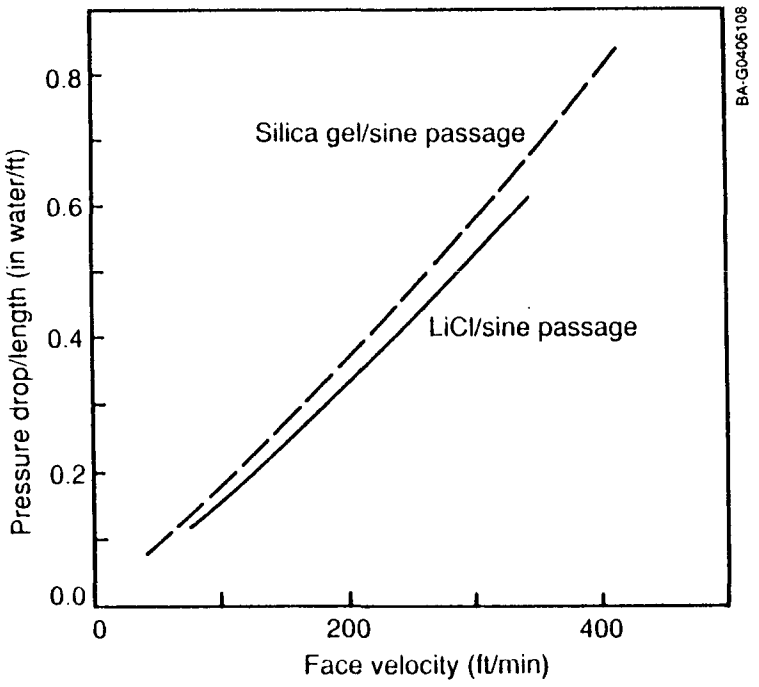
Pressure Drop Across Two Dehumidifier Test Matrices



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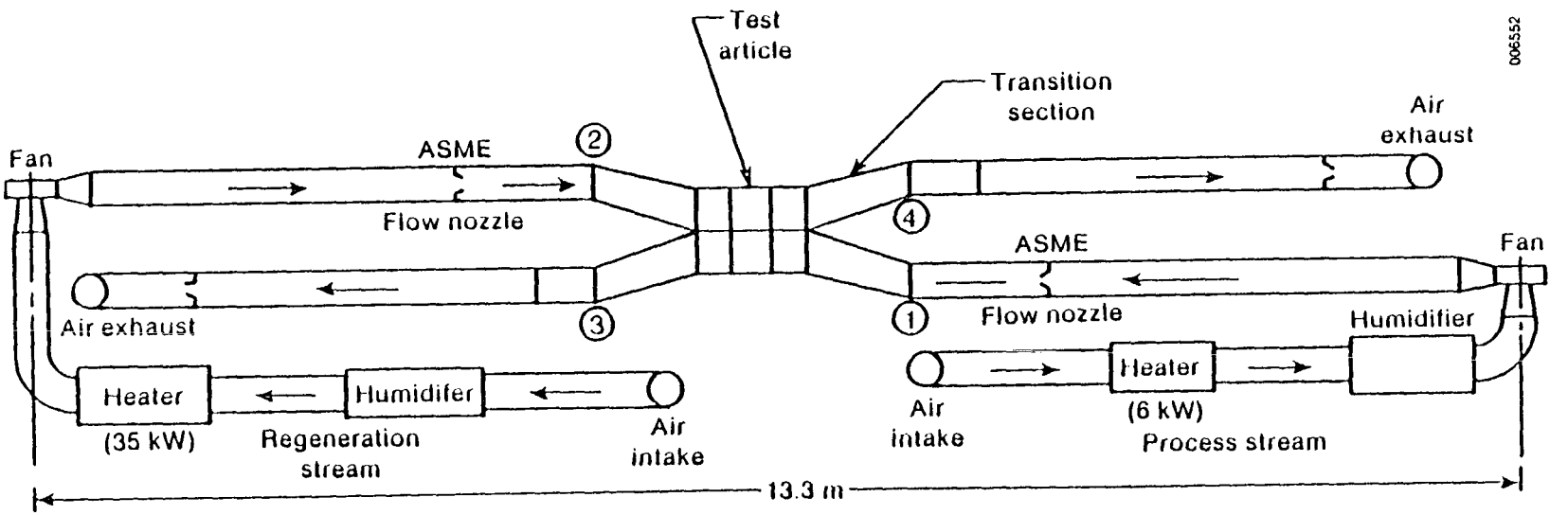
Desiccant Cyclic Test Facility



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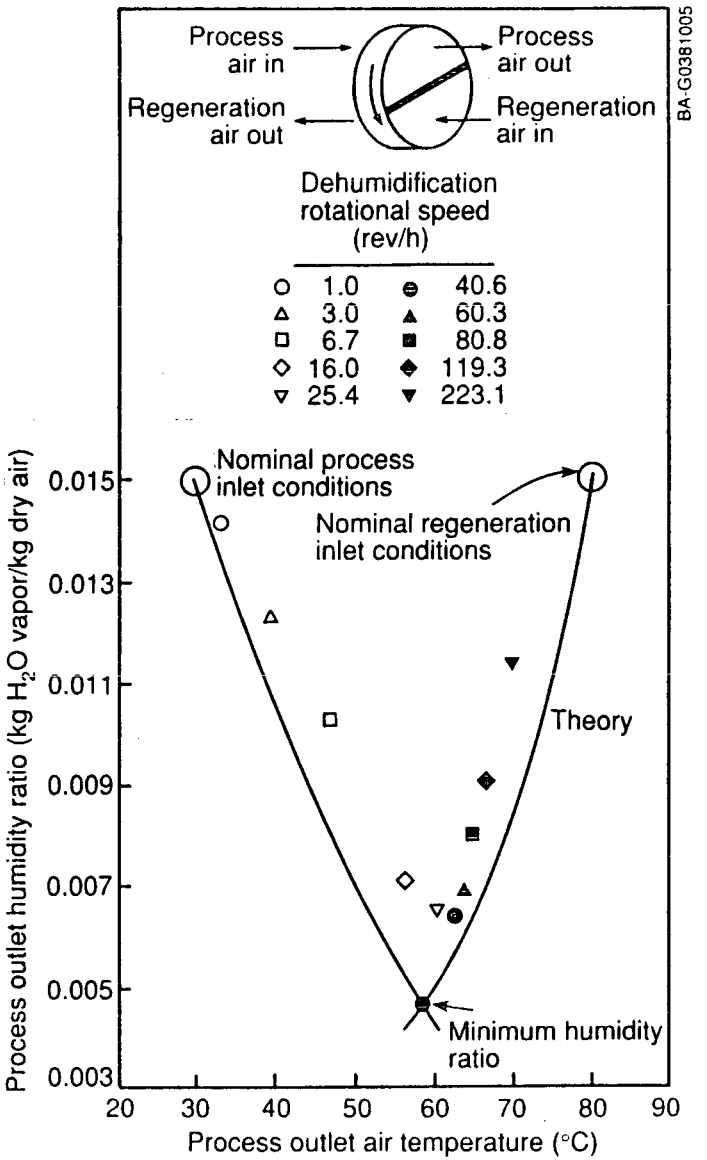
Experimental Results from Cyclic Test Facility



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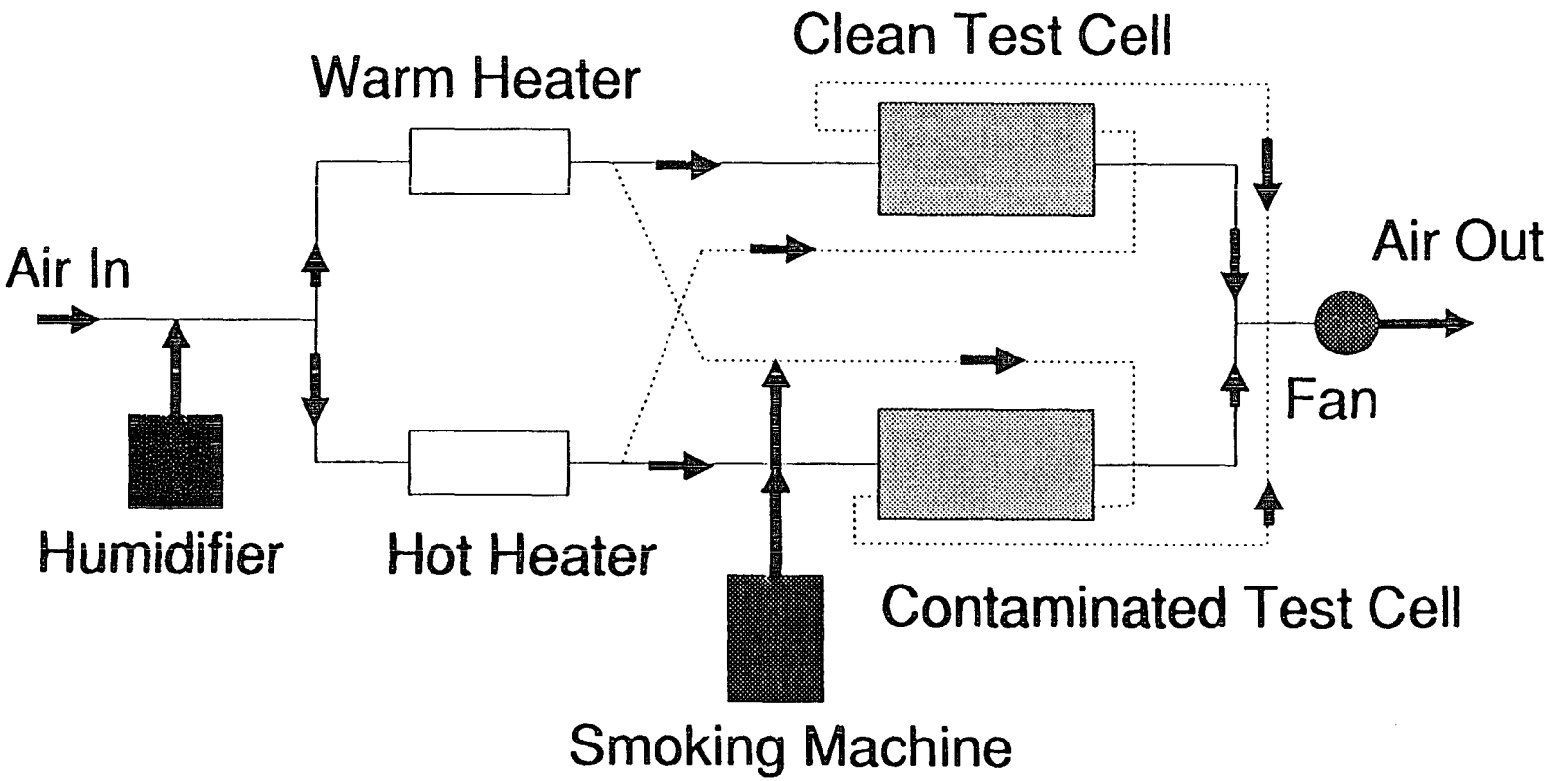
Desiccant Contamination Test Facility



——— Warm air in clean test cell & hot air in contaminated cell

····· Hot air in clean test cell & warm air in contaminated cell

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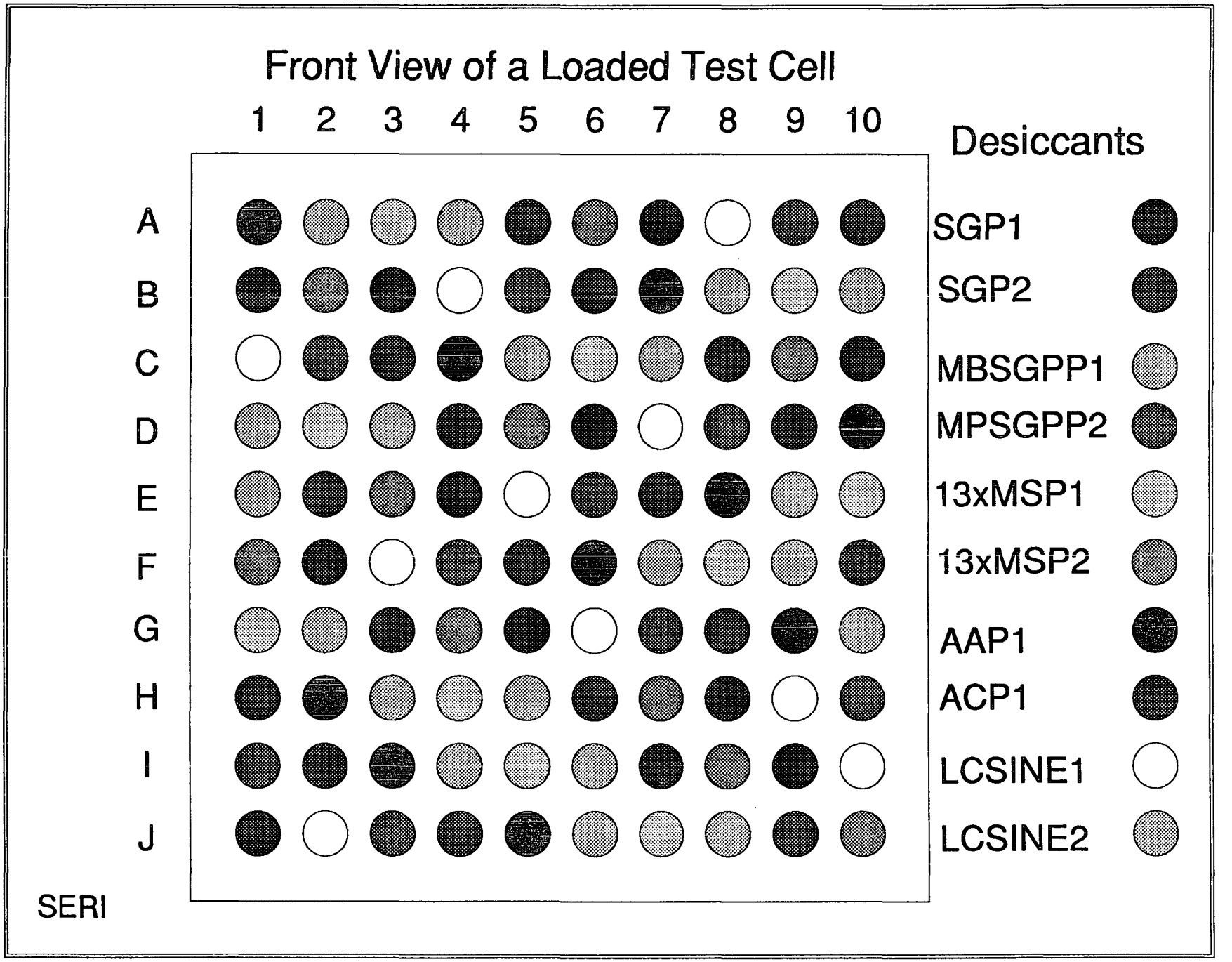
Front View of a Loaded Test Cell
1 2 3 4 5 6 7 8 9 10
A
B
C
D
E
F
G
H
I
J
Desiccants
SGP1
SGP2
MBSGPP1
MPSGPP2
13xMSP1
13xMSP2
AAP1
ACP1
LCSINE1
LCSINE2
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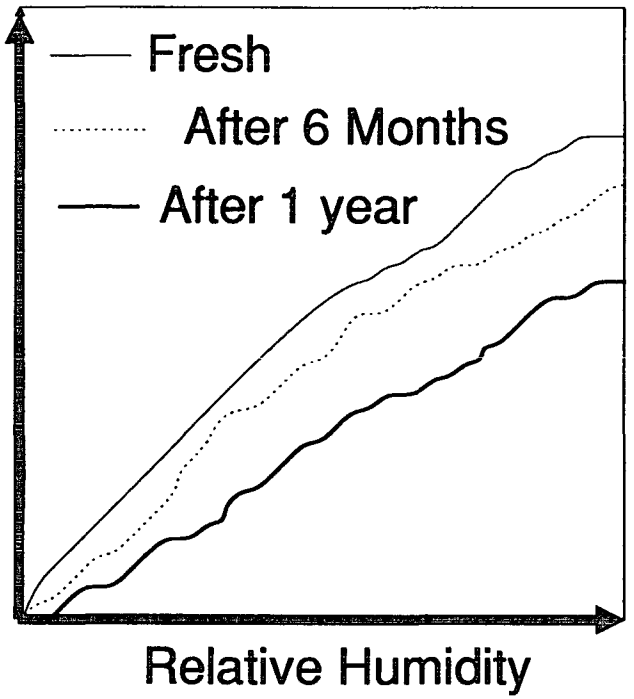
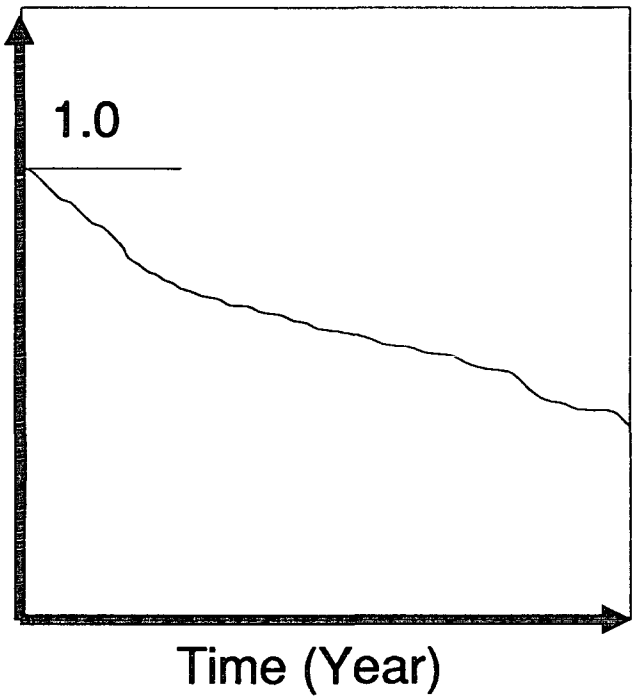
Desiccant Contamination Research

Anticipated Results

Desiccant Water Content



Normalized Performance



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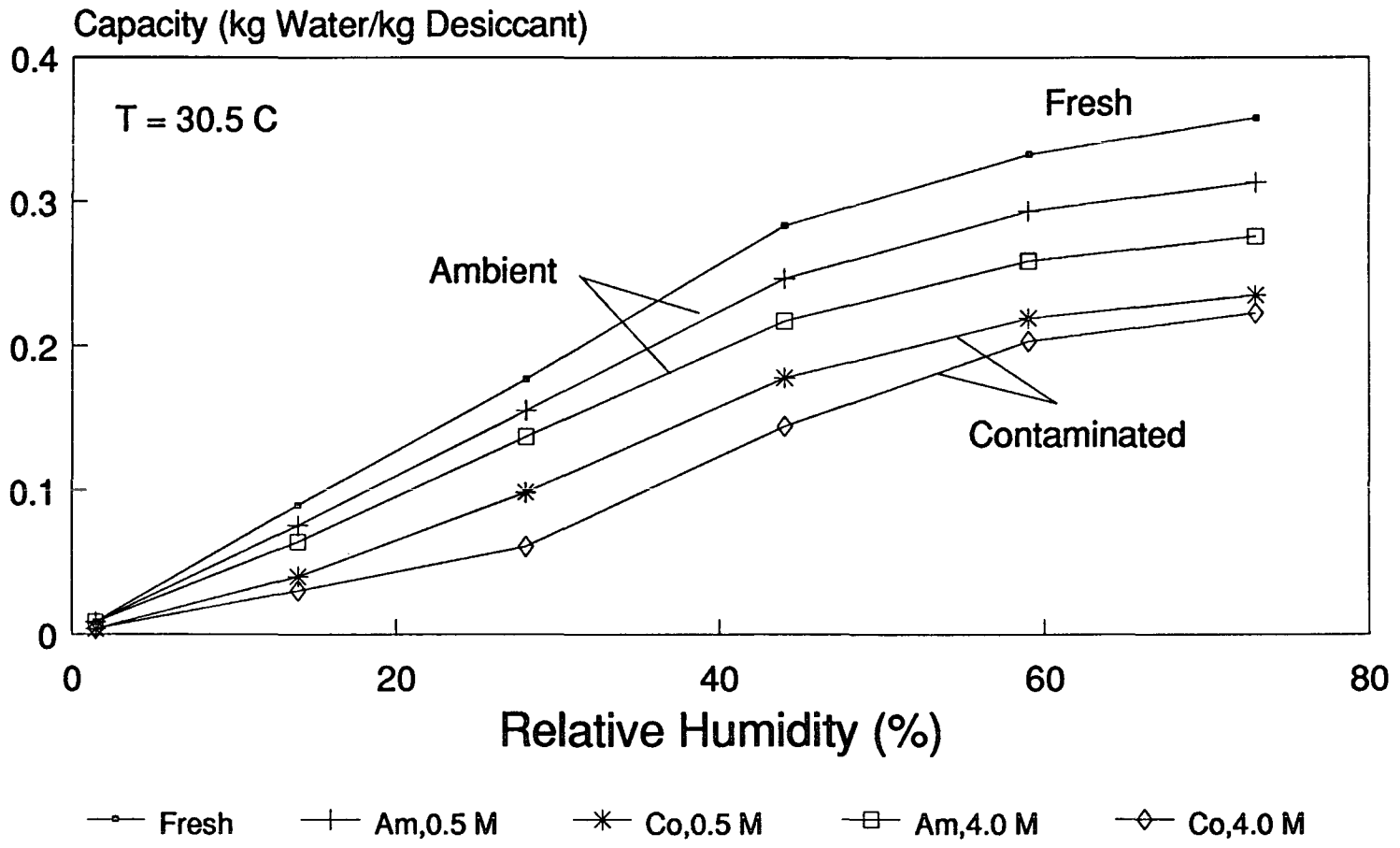
Moisture Capacity of Silica Gel
Exposed to Ambient and Contaminated Air



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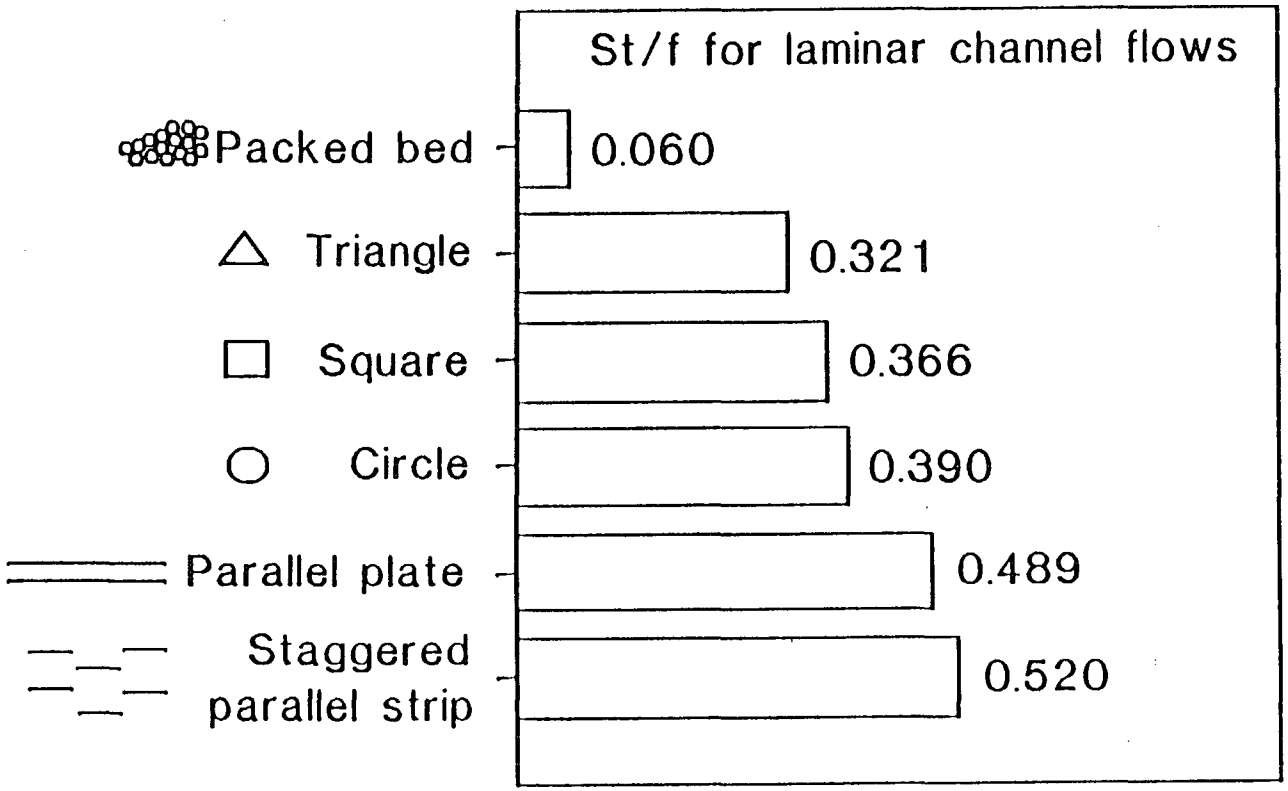
SERI's Desiccant Capabilities

Analytical Tools

- Materials Models
  - Isotherms
  - Solid-side Diffusion
- Matrices Models
  - Heat and Mass Transfer
  - Pressure Drop
- Components Models
  - Performance
  - Effectiveness
- Systems Models
  - Desiccant Cycles
  - Hybrid Cycles

Dehumidifier Geometries

- Convective heat and mass transfer rates (St)
- Pressure drop (f)



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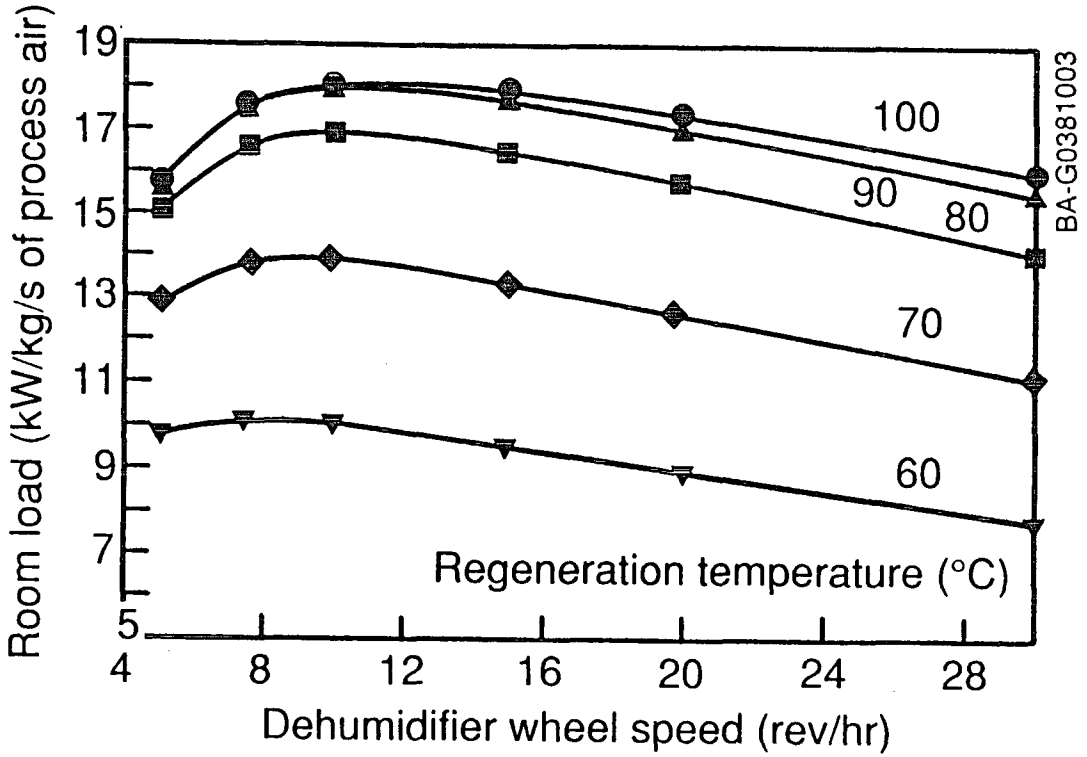
Effect of Dehumidifier Wheel Speed and Regeneration Temperature on Ventilation Cycle



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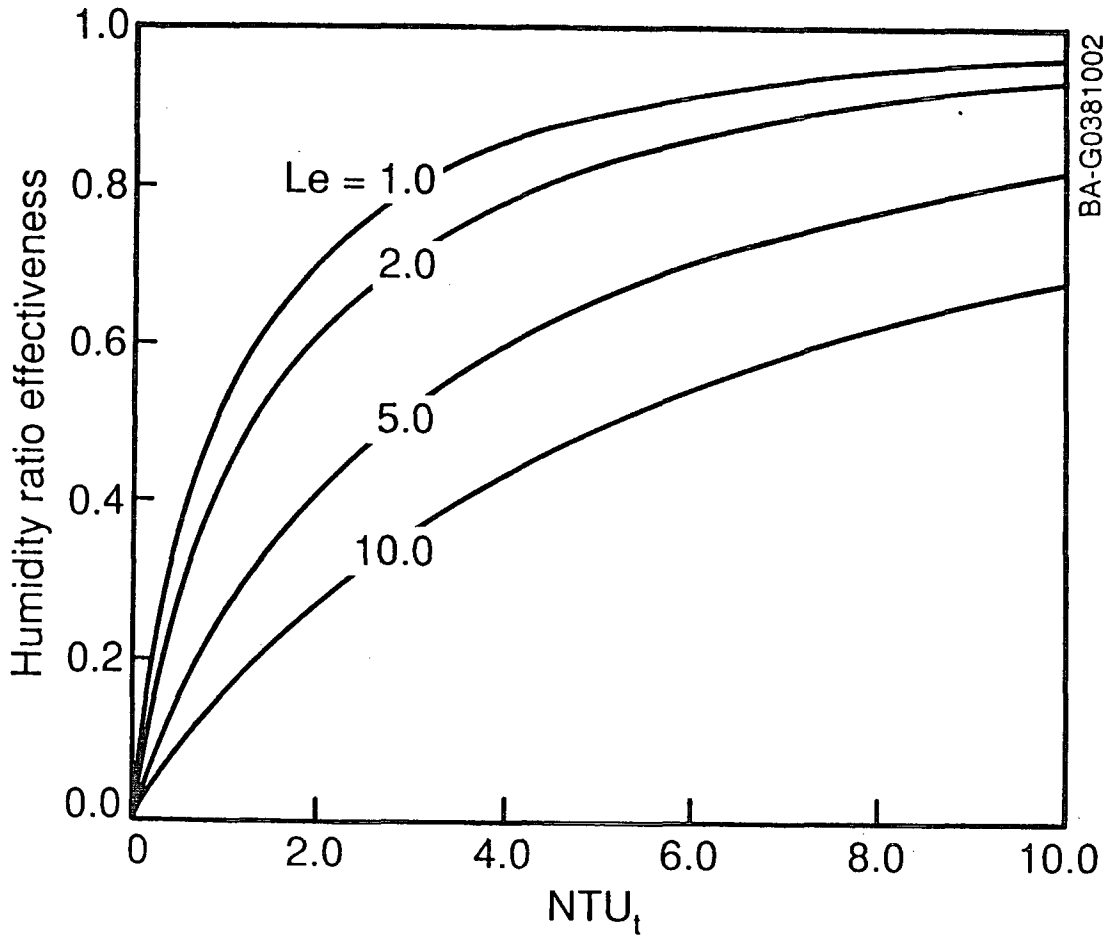
Impact of Heat and Mass Transfer Parameters on a Dehumidifier Effectiveness



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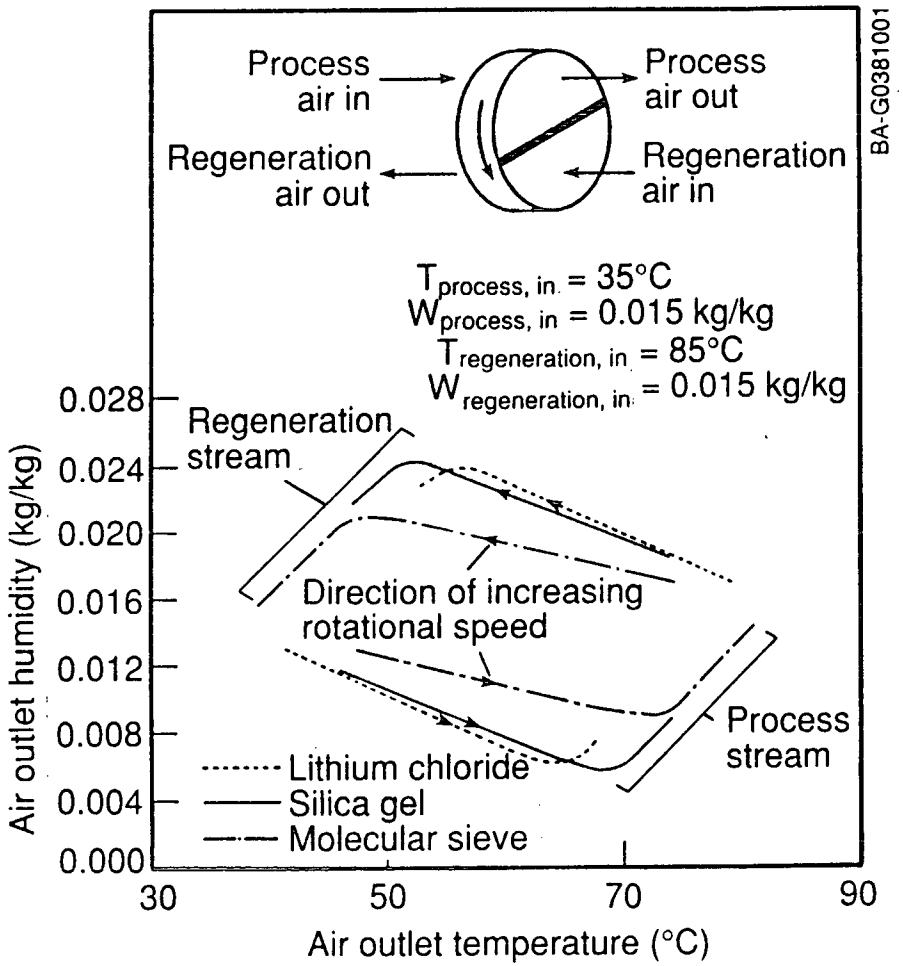
Impact of Desiccant Material on Dehumidifier Performance



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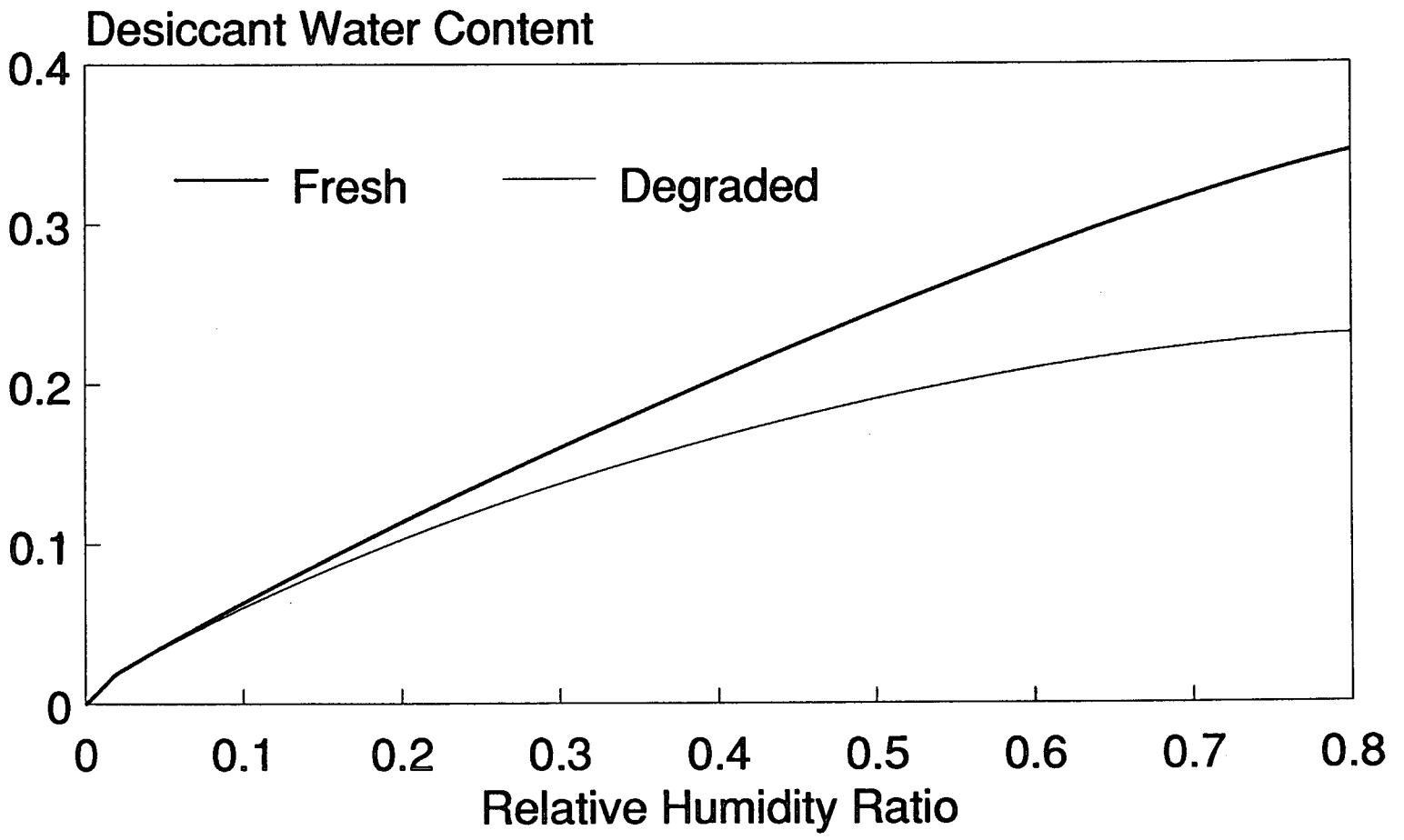
Degraded Desiccant (Silica Gel)

Changed Isotherm Shape



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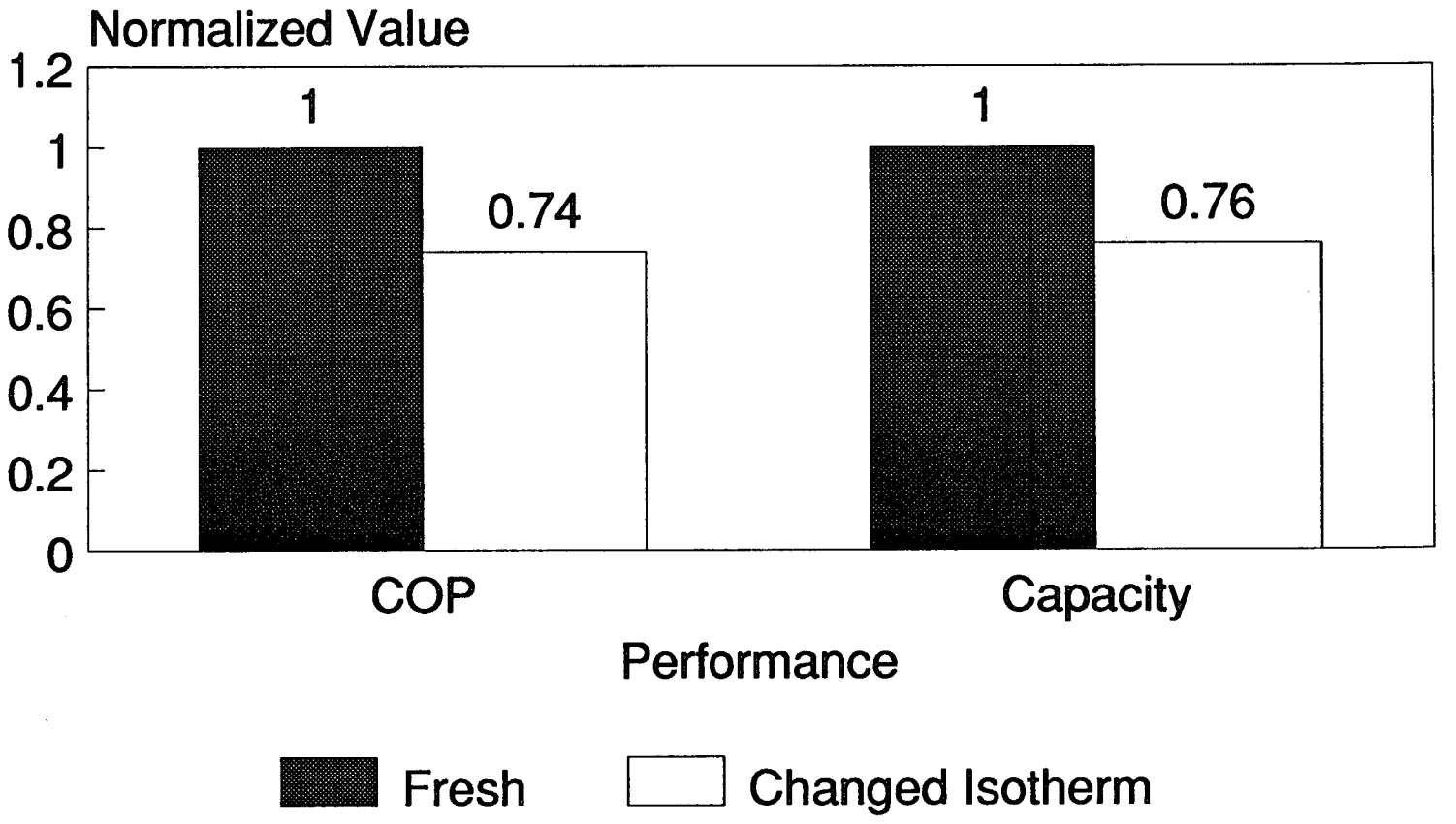
Effect of Desiccant Degradation

Changed Isotherm Shape



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SERI's Desiccant Capabilities
Development and Characterization

- Development of desiccant materials, dehumidifier matrices, dehumidifier wheels, and new system cycles
- Characterization of sorption properties of polymeric and inorganic desiccant materials
- Characterization of heat and mass transfer performance of dehumidifier matrices
- Characterization of performance of dehumidifier wheels
- Characterization of interaction between desiccants and air-borne contaminants
- Analysis of advanced desiccant and hybrid cycles and systems

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SERI's Desiccant Capabilities

Knowledge of State-of-the-art in Industry

- Active in desiccant workshops, technical conferences, and ASHRAE activities
- Knowledge of almost all of organizations and people involved with desiccant cooling and dehumidification
- In close contact with major HVAC players involved in the technology
- Aware of almost all of (proprietary and non-proprietary) desiccant activities in the industry and research community

SERI Desiccant Research

FY 1989 Key Accomplishments

- Developed, modified, and characterized several desiccant polymers such as PSSASS and PSSALS (identified PSSALS as the most favorable with best isotherm and kinetics)
- Characterized and evaluated several advanced composite desiccants and matrices for low-temperature regeneration applications (identified Empore composite to be most promising with 10% increase in performance and 30% reduction in size of a dehumidifier)
- Investigated degradation of several desiccants due to thermal cycling and air-borne pollutants (an apparatus was fabricated and contamination test started and ongoing)

Desiccant Cooling Research
SERI as the Lead Laboratory

- Experienced technical staff
- Capable management
- Respected nationally and internationally
- Multiple unique test facilities
- Analytical tools
- More than 60 papers, reports, M.S. and Ph.D. thesis
- More than 30 national and international talks
- Member of ASHRAE sorption committee (TC3.5)
- Advisory board to ASHRAE Dehumidification Handbook
- Co-editor of Desiccant News Letter
- Co-sponsor of multiple desiccant workshops
- Collaborations with industry

Organizations Contributing to
Desiccant Cooling Technology and Research

Open Cycle

Liquid

ASU
CSU
U. Wisconsin
GRI
G. Meckler
M. Meckler
Kathabar
Battle Columbus
SERI
DOE

Solid

SERI
CSU
FSEC
U. Wisconsin
IIT
U. Texas A&M
GRI
U. Illinois
G. Meckler
Cargocaire
Tecogen
ADL

ICC
SIMCO
ASK
DOE
ORNL
U. Reno

Gard
Eaton Corp.
Larouche Chem.
RTI
Penn State
U. Pittsburgh
3M
IITRI

Closed Cycle

Solid

Zeopower
GRI

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Desiccant Cooling Technology

What We Learned in the Last Decade

Materials

Silica gel: Good commercially available desiccant
Molecular sieve: Not suitable, low capacity
Lithium chloride: Good capacity, corrosive, hard to contain
Glycols: Not suitable, high vapor pressure
Substrates: Interaction of desiccant and substrates
Polymers: Can be modified to be good desiccants
Particle size: Should be less than 100 micron
Ideal desiccant: A function of regeneration temperature
(T<210 F, 10%-20% better than silica gel)
(T=320 F, 20%-40% better than silica gel)
Form/shape: Should be suitable for incorporation into a channel flow geometry
Selective Adsorption: Dependenig on the choice of desiccant certian indoor air pollutants can be removed

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Desiccant Cooling Technology
What We Learned in the Last Decade (Cont.)

Components

Dehumidifier: Requires high heat and mass transfer rates (NTU>15)
Requires low pressure drops
Must have channel-flow geometry
10% non-uniformity causes 50% reduction in NTU
1% reduction in effectiveness due to 1% leakage between processs and process airstreams
Stage regeneration improves performance by 20% to 40%
Should cost less than $150/ton
Validated dehumidifier models

Heat Exchangers: High effectiveness (>90%) necessary

D/E coolers: Sufficient effectiveness

I/E coolers: Can improve the performance of cycles

Desiccant Cooling Technology
What We Learned in the Last Decade (Cont.)

Systems

System Performance: COP from 0.5 to 1.1 in 10 years
Validated sytem models
through experimental data

Packed bed system: Low performance, high parasitics

Cooled bed: Complex configuration, no significant advantage over adiabatic beds

Liquid systems: Large capacity (>10 ton), corrosion
Roof-top open-flow systems
feasible in certain climates

Advanced cycles: Improve COP to 2 and capacity by 50%

Hybrid cycles: Increase COP to 1.5 and capacity 50%

Energy sources: Waste heat, natural gas, solar, and off-peak electricity

Advantages: High energy efficiency, no or low use of CFCs, Improved IAQ and comfort

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Desiccant Cooling Technology
What We Learned in the Last Decade (Conc.)

Market

Cost: Competitive with V/C in regions with high gas-electricity cost ratios
Low cost dehumidifier essential

Size: Important and sometimes deciding factor

Fuel: Gas cooling for peak reduction, off-peak electricity for peak shifting

Current Applications: Supermarkets, hotels, restaurants, swimming pools, health clubs

Commercial Systems: Cargocaire, ASK, Kathabar, EIS

Driving Forces: Comfort, IAQ, CFCs reduction, and energy efficiency

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Desiccant Cooling Technology
Knowns/Unknowns

- Knowns
  - Reliable desiccant and dehumidifier test data
  - Validated models for design and analysis
  - Parameters affecting performance
  - Advantages/limits
  - Market potential
  - Energy impacts
  - Cost premium for present systems
- Unknowns
  - Development of low-cost, efficient, compact and reliable solid dehumidifiers
  - Development of non-corrosive, low-vapor-pressure, and efficient liquid desiccant materials
  - Performance degradation of desiccants and dehumidifiers
  - Field test performance of advanced cycles
  - Approaches for market acceptance and growth

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Desiccant Cooling R&D
Major Issues

- Advanced solid and liquid desiccants
- Low-cost, compact, reliable dehumidifiers
- Low-cost, compact, reliable systems
- Application and market growth

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SERI Desiccant Cooling R&D Major Efforts

- Advanced desiccants/components
  - Composites
  - Solid polymers
  - Liquid polymers
- Reliability
  - Desiccant contamination/degradation
- Advanced cycles
  - Component and system analysis

Major Trusts
for Advancing Desiccant Cooling Technology

- Development of low-cost, efficient, reliable, and compact solid dehumidifier equipment
- Development of non-corrosive, low-vapor-pressure, and efficient liquid desiccant materials for liquid dehumidification equipment

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Desiccant Cooling Research
Industry Collaborations

SERI Contributions

Materials development

Materials characterization

Matrices characterization

Components characterization

Components analysis

Systems analysis

Technology transfer

Industry Contributions

Materials development

Matrix development

Components development

Systems development

Field characterization

Hardware fabrication

Market analysis

SERI's Desiccant Cooling Research

Current Collaborations with Industry

- Innovative desiccant composites (3M/GRI)
- Polymeric desiccant characterization (Eaton/GRI)
- Desiccant cooling system analysis (Texas A&M)
- Polymeric desiccant development (Kodak)
- Advanced dehumidifier matrices development (CEC)
- Liquid desiccant polymers (MENG/QDT/GRI)

Desiccant Cooling and Dehumidification

Potential of the Technology

- Desiccant systems are 15% to 40% more efficient than conventional chillers in meeting latent load
- Replacing conventional chillers with desiccant systems can save about 0.05 quads of energy for air conditioning of buildings each year
- Desiccant systems are currently suitable for niche applications such as supermarkets
- Desiccant systems reduce or eliminate the use of CFCs

Desiccant Cooling Technology
Benefits

- Significant energy savings
  (Reduction of greenhouse gases)
- CFC reduction
- Peak energy reduction
- Improved comfort
- Improved indoor air quality (IAQ)
- Improved productivity

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