Air Conditioning for Hot-and-Humid Climates:
Commercial Technologies

ACEEE Market Transformation Conference

Emerging Technologies

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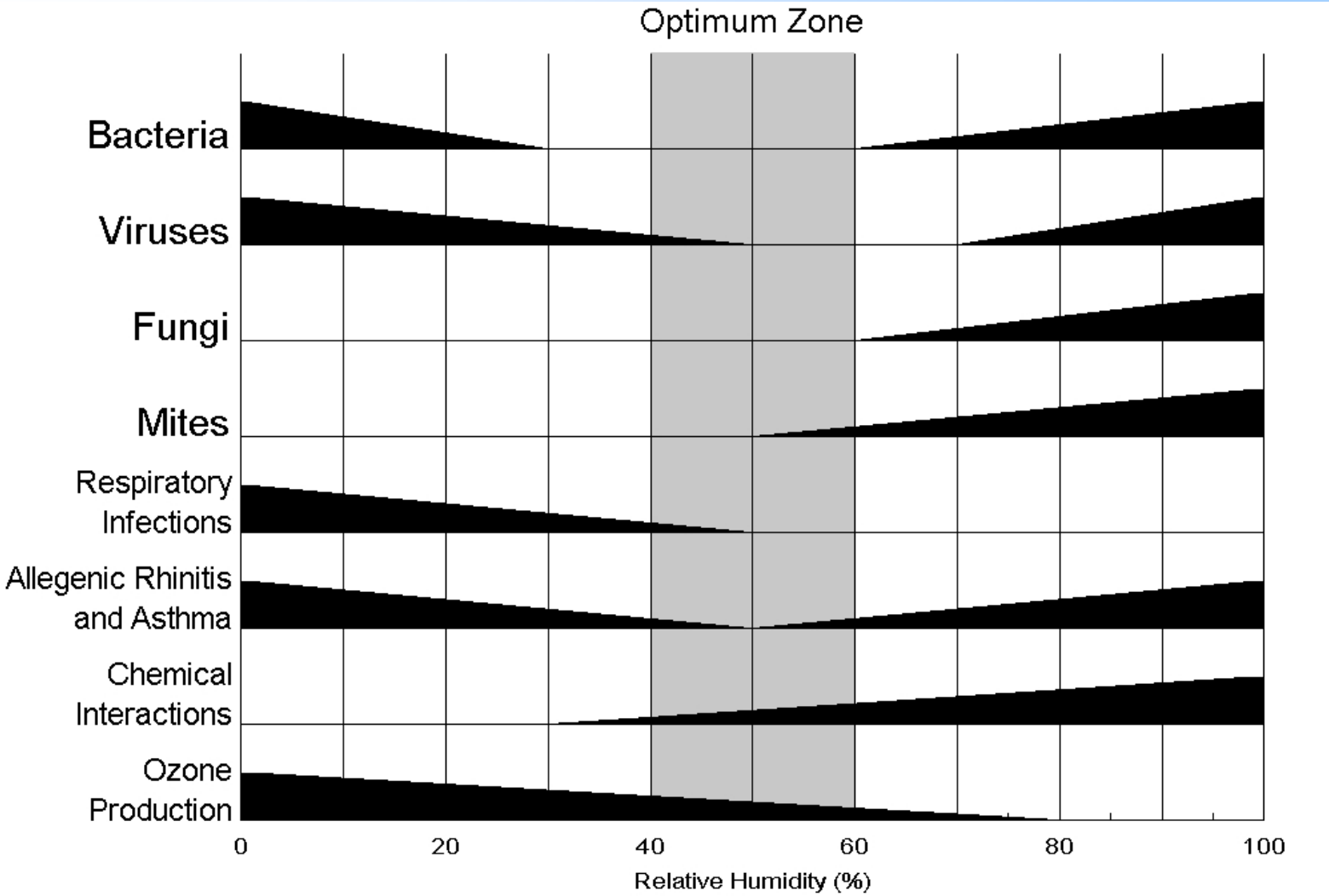
Overview

- The Need for Humidity Control
  - building applications with greatest need
  - HVAC Control issues
- Technologies to Control Humidity
  - active humidity control
  - enhanced cooling systems
  - ventilation pretreatment
- The Cost of Humidity Control
  - which technologies are best?

What Should Humidity Levels Be?

Maintain space below 60-65% RH



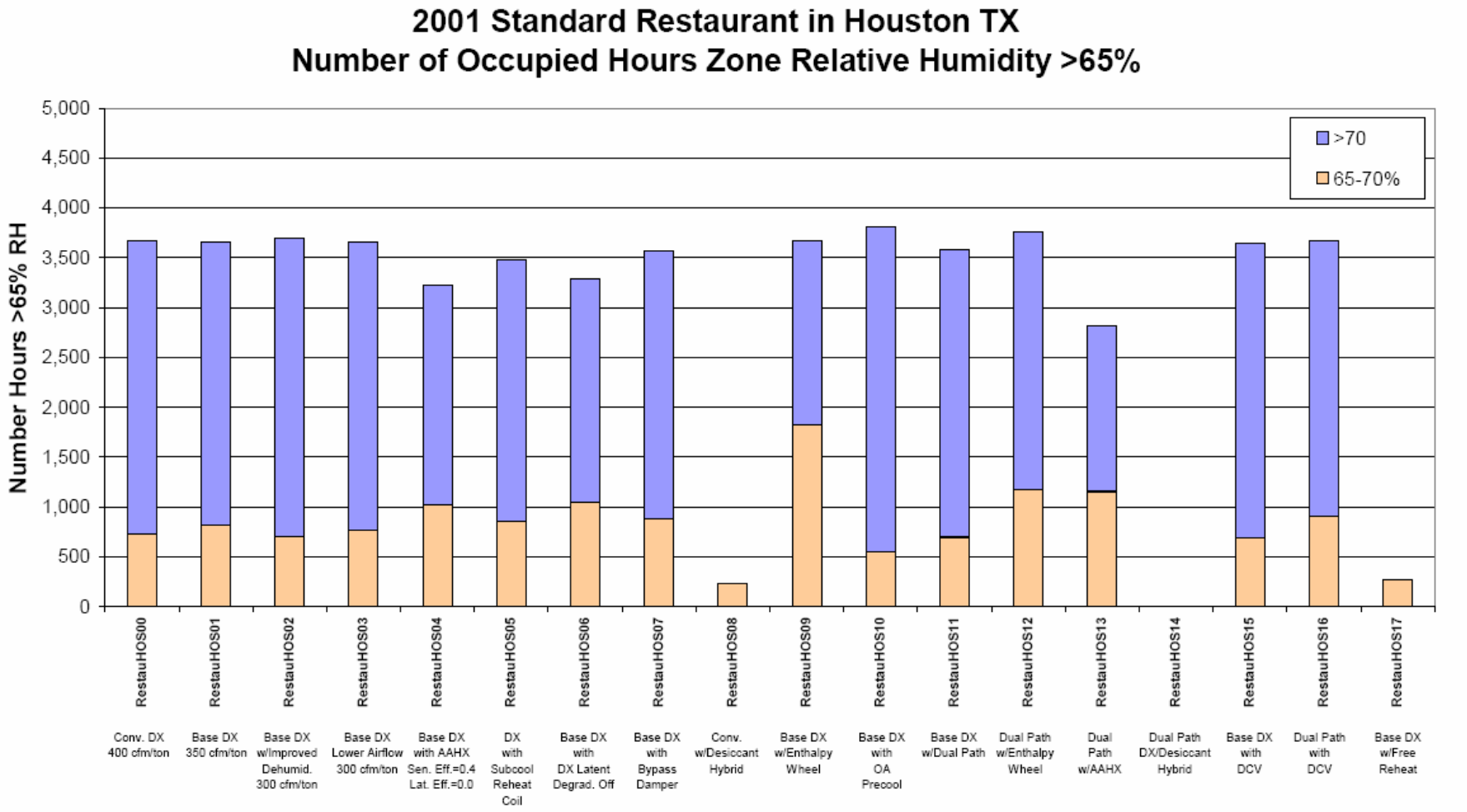
Adapted from Sterling, Arundel & Sterling 1985

Where is Humidity a Concern?

- Applications with High Ventilation
  - outdoor air is largest source of moisture
- Applications with Low Sensible Cooling Loads
  - display cases in supermarkets provide cooling
  - theatres with high occupancy, but no windows or lights
- Applications where HVAC Design/Controls Degrade Latent Performance
  - evaporation of moisture from cooling coil when cooling is off but fan continues to operate

High Humidity Hours

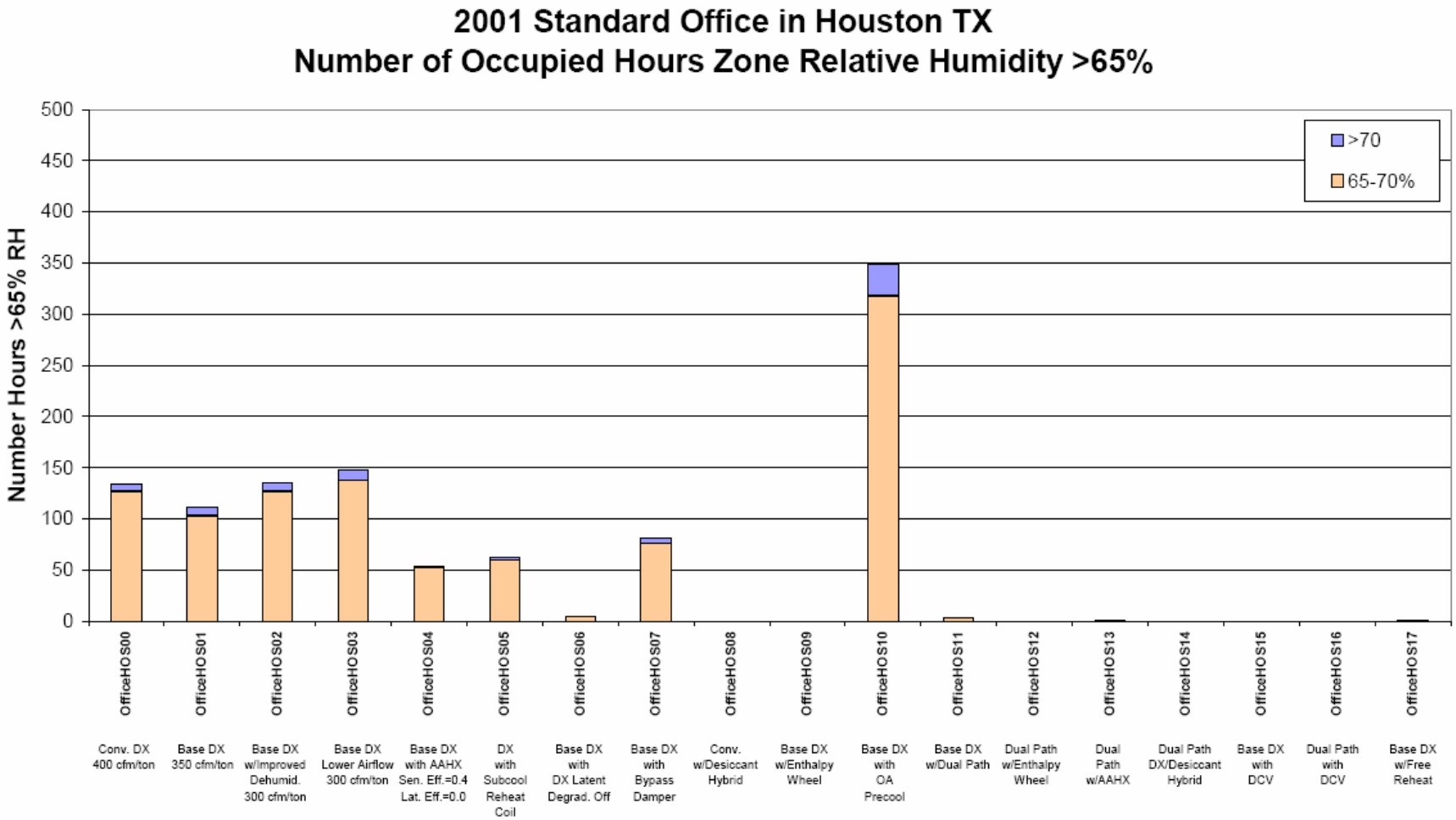
Houston Restaurant



ASHRAE 1254-RP Final Report

High Humidity Hours

Houston Office



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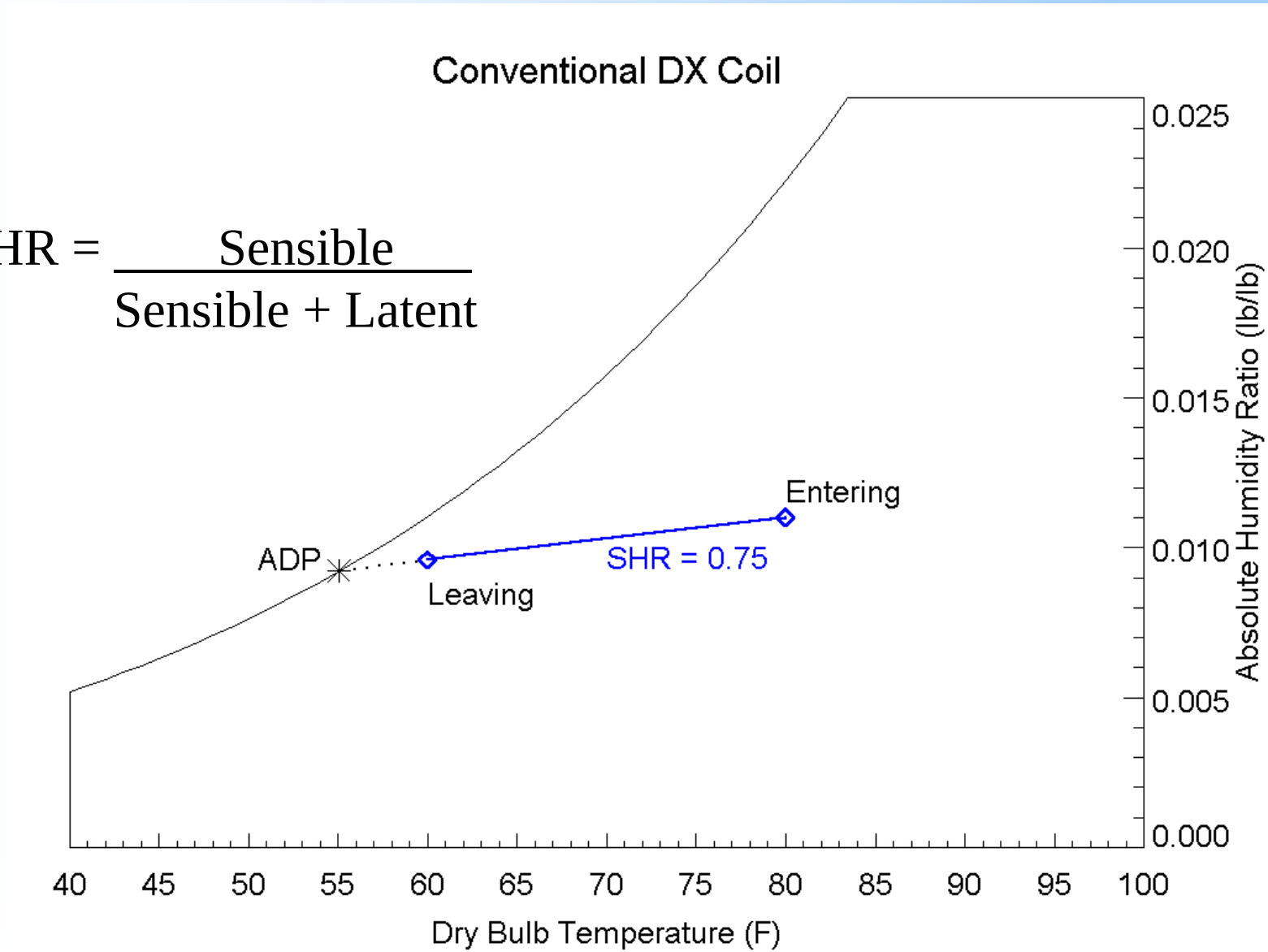
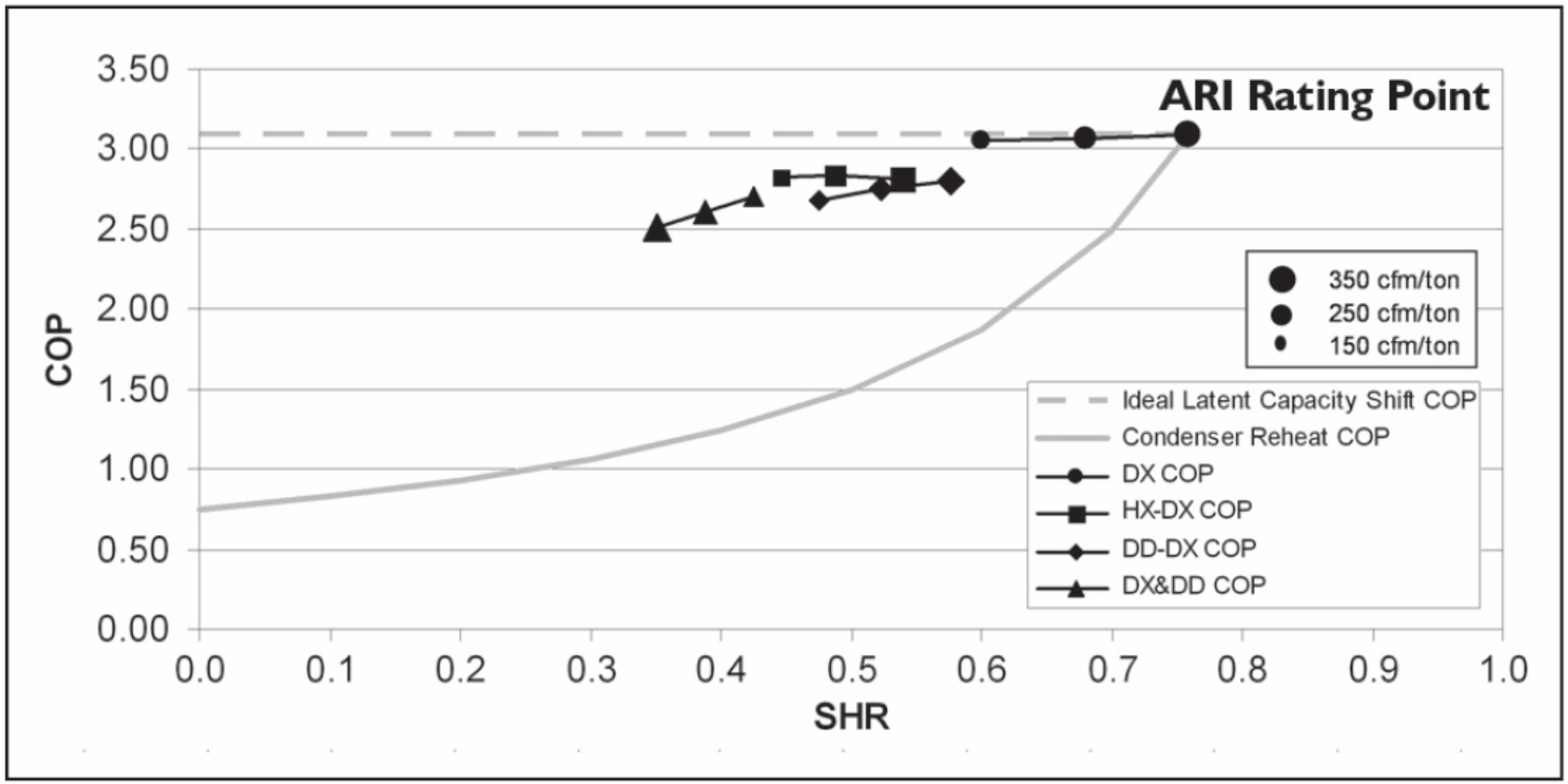
Conventional Cooling Coil

$$SHR = \frac{\text{Sensible}}{\text{Sensible + Latent}}$$

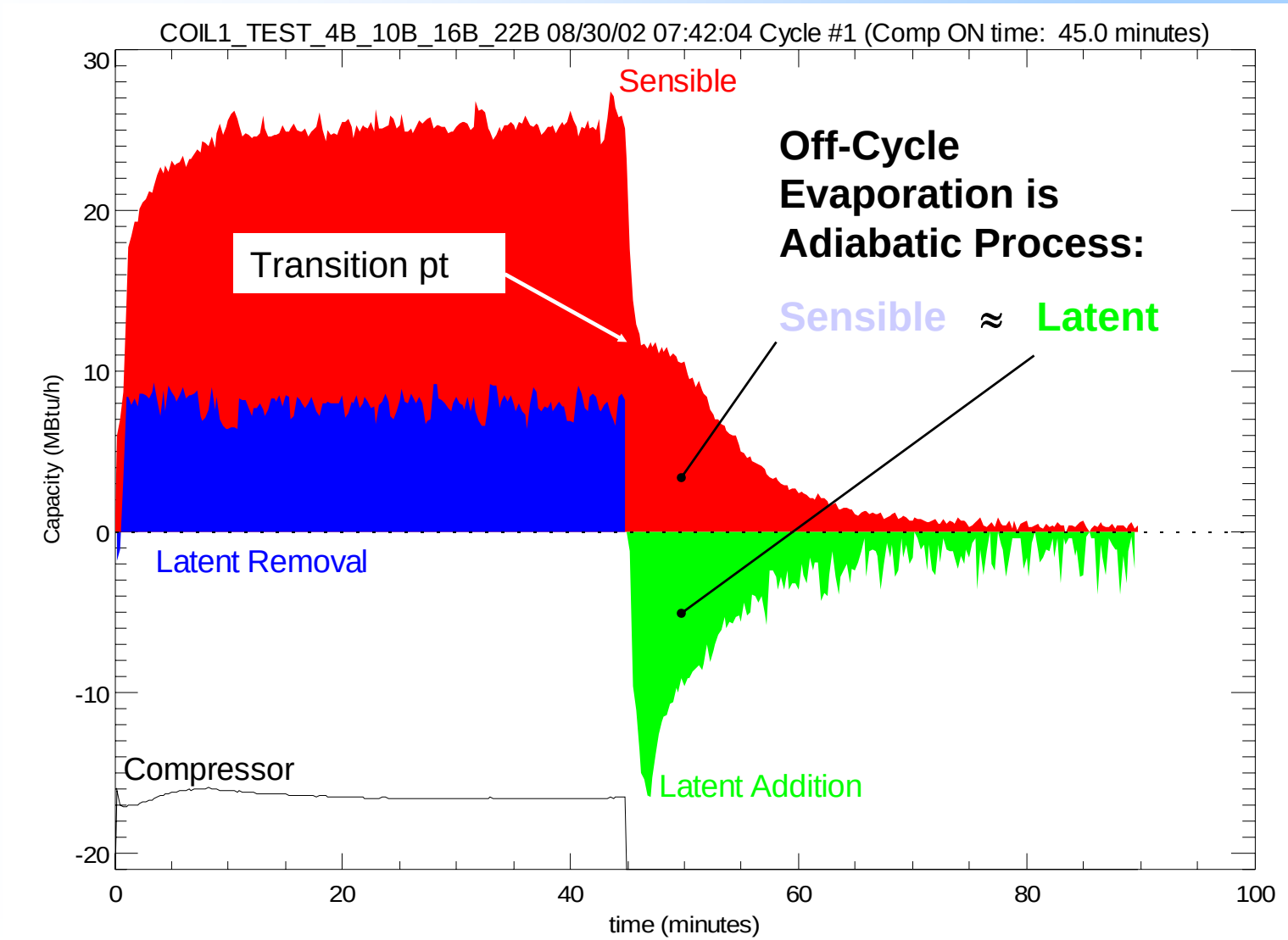


Better Dehumidification means Lower Efficiency



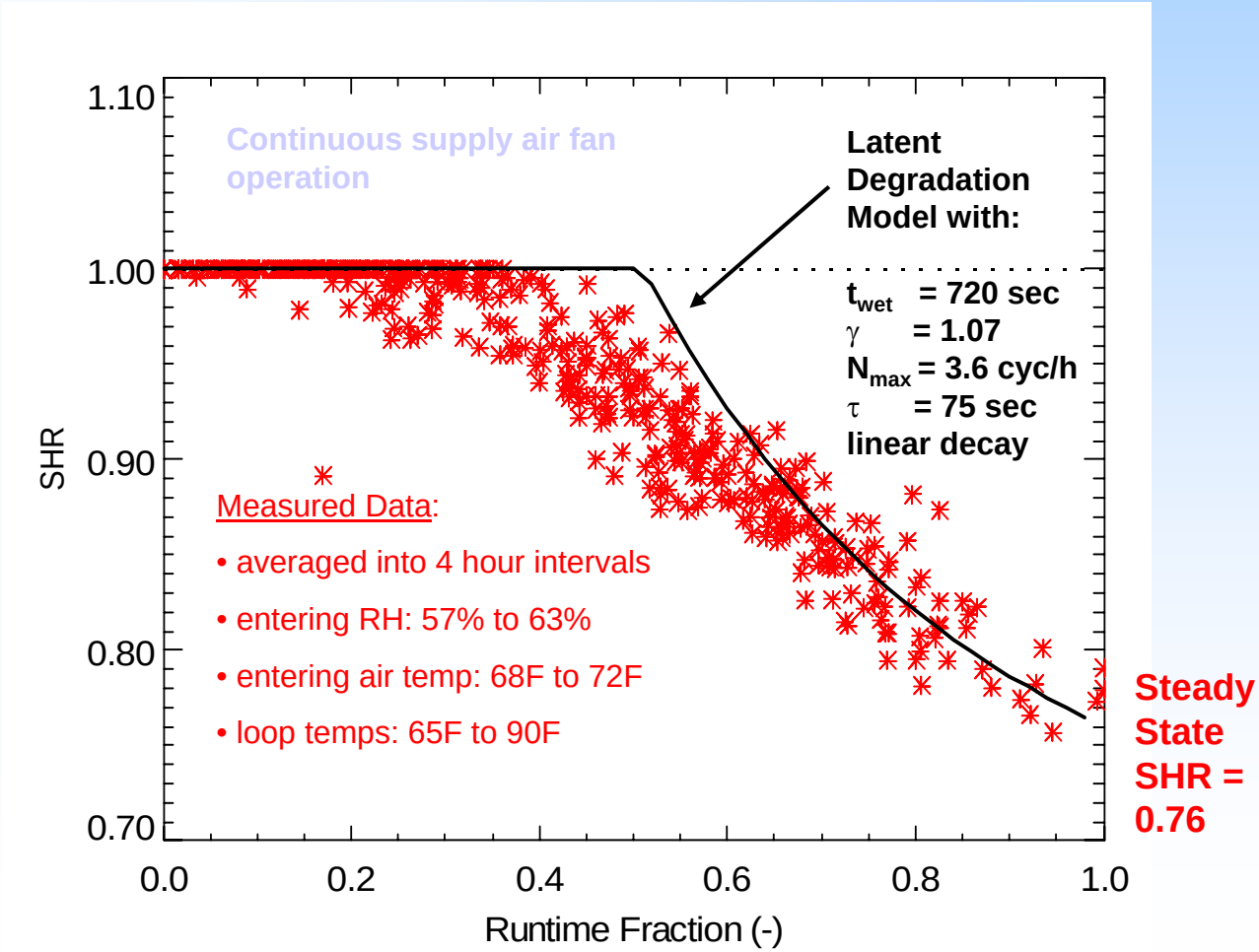
Kosar – ASHRAE Journal 2006

Sensible and Latent Capacity With Continuous Supply Air Fan Operation



Latent Degradation at Part Load

Shirey, Henderson & Raustad (2006)

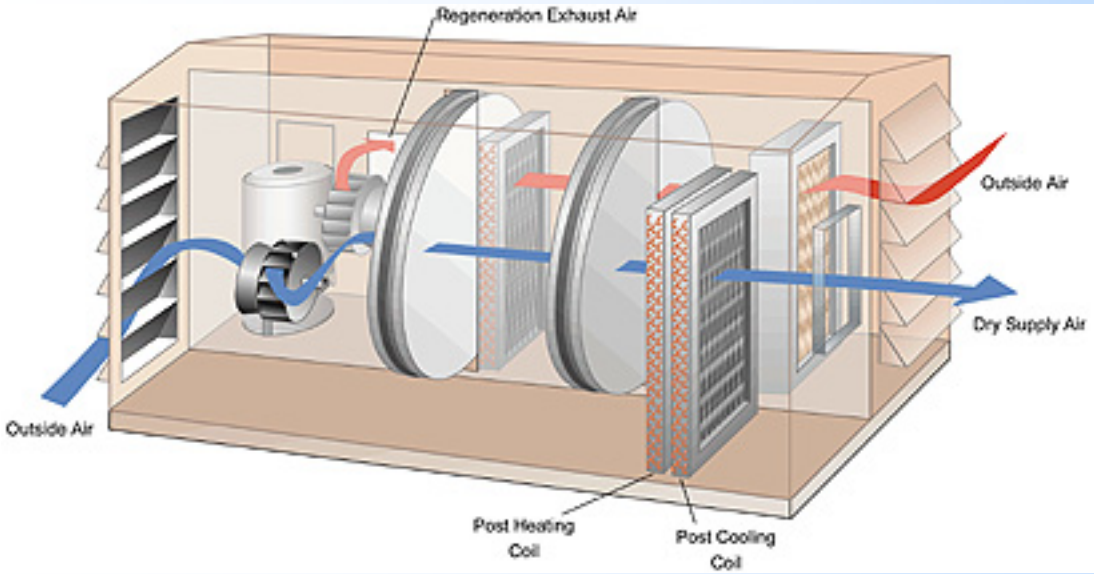


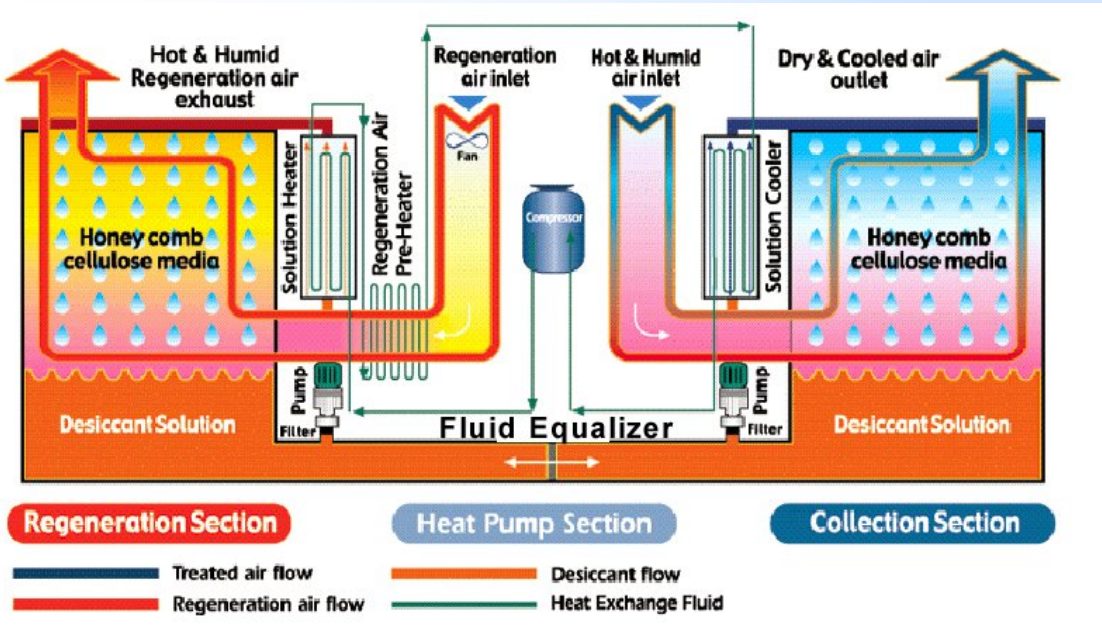
Novel Dehumidification Technologies

- Enthalpy wheels (recover heat and moisture)
- Gas-fired desiccant wheel systems
- Liquid desiccant systems
  - Electric heat pump systems
  - Thermally activated systems
- Hybrid electric desiccant system

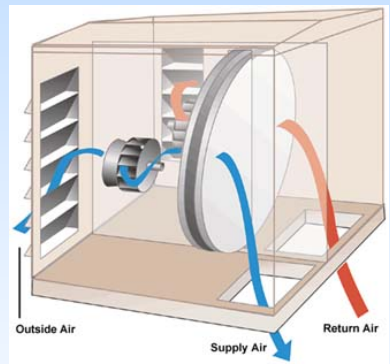
Desiccant Technologies

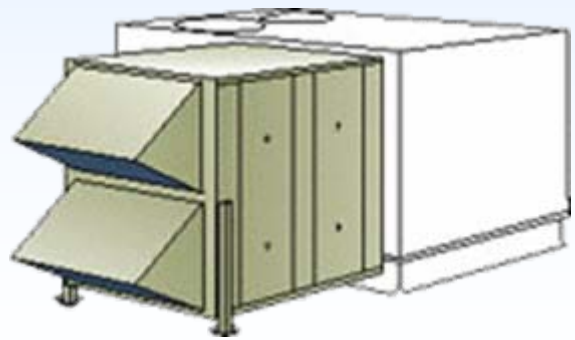
Gas-fired Desiccant Wheel Unit





Liquid Desiccant Heat Pump (Drykor)

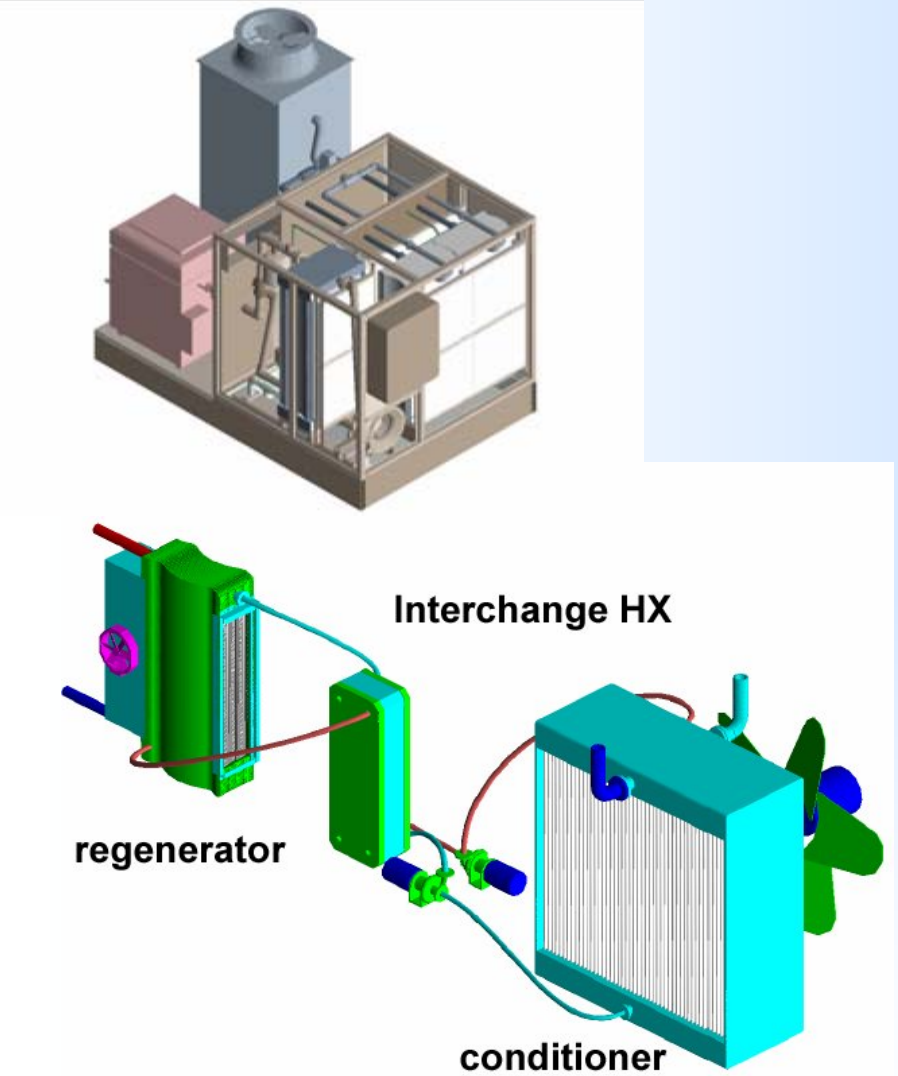




Enthalpy Wheel

Recent Improvements

Liquid Desiccants

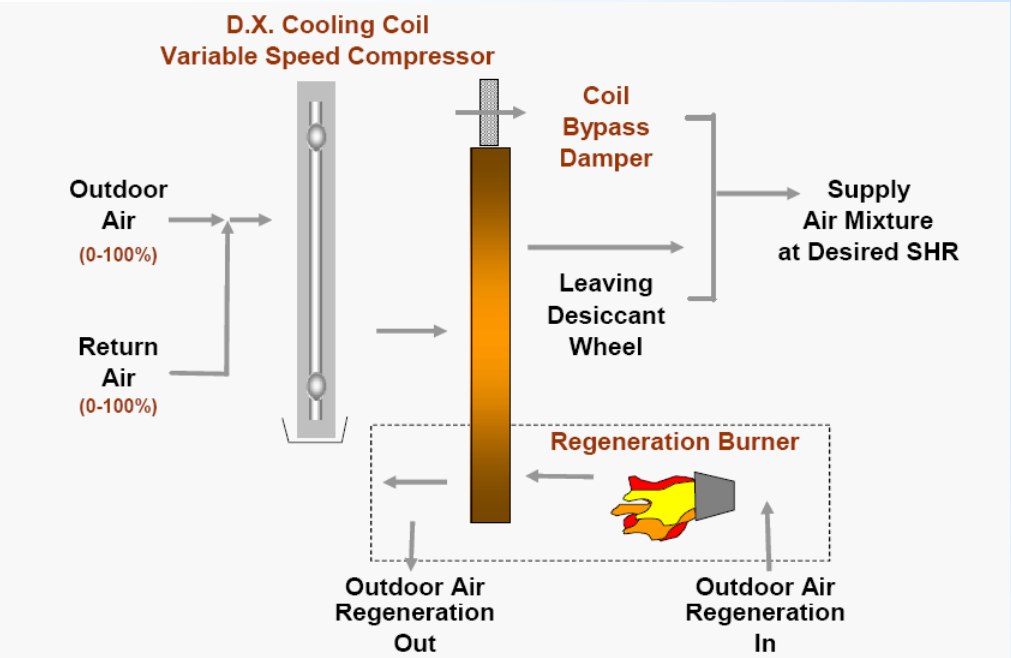


Thermally Activated Liquid Desiccant (AIL Research)

- *Low Flow Absorber low carryover*
- *1-½ Effect Regeneration provides better efficiency*
- *More compatible with solar thermal (e.g., hot water)*

Recent Improvements

Gas-Fired Hybrid Desiccants



Hybrid Desiccant Unit (Semco)

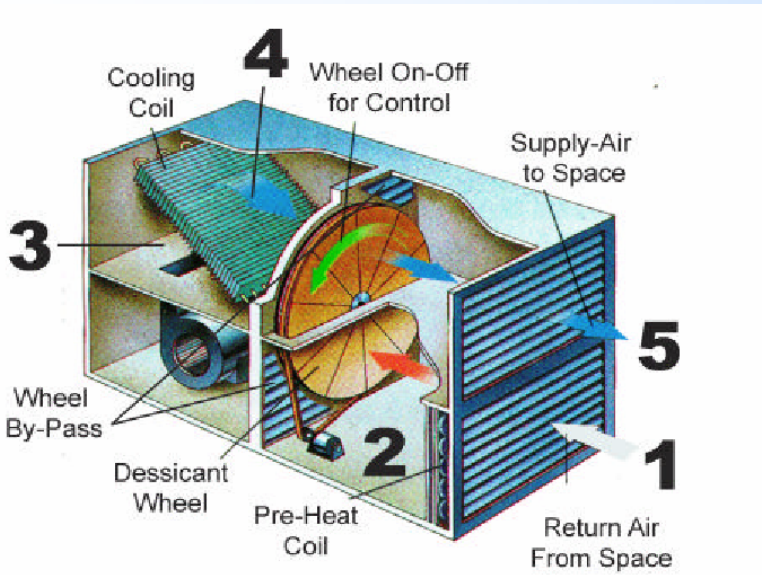
- *Smaller Desiccant Wheel treats a portion of supply air stream*
- *Desiccant "likes" cool high RH inlet air*
- *Hybrid approach uses advantages of each system*

Recent Improvements

Electric Hybrid Desiccants

Munters HCU

- *Combine desiccant wheel with vapor compression*
- *HCU uses condenser heat to regenerate desiccant wheel*
- *CDQ uses desiccant to enhances cooling coil SHR*



Cromer Cycle (Trane CDQ)

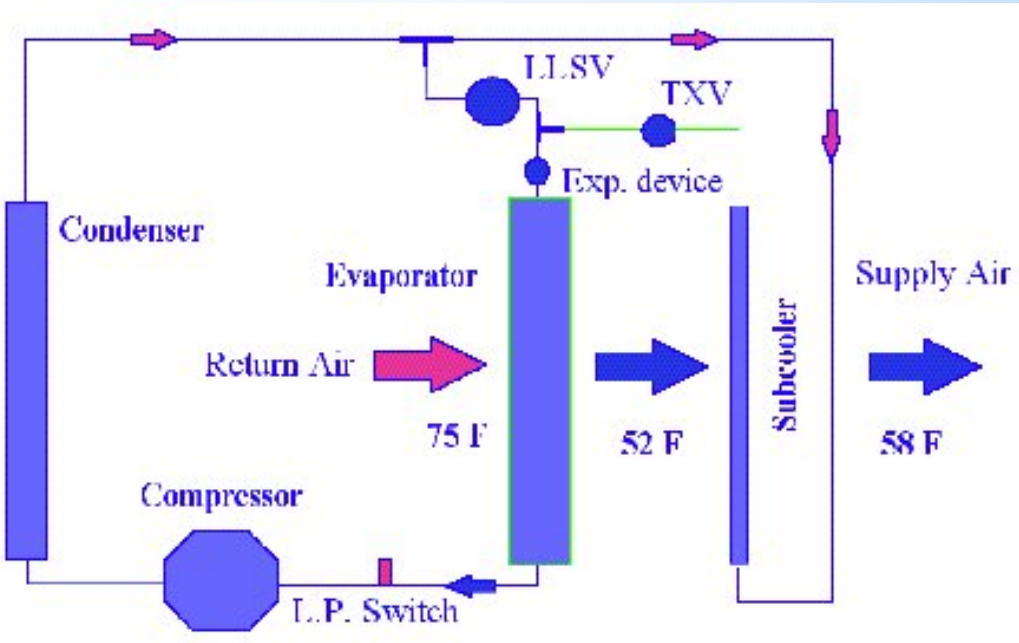
Improving AC Performance

Lowering SHR

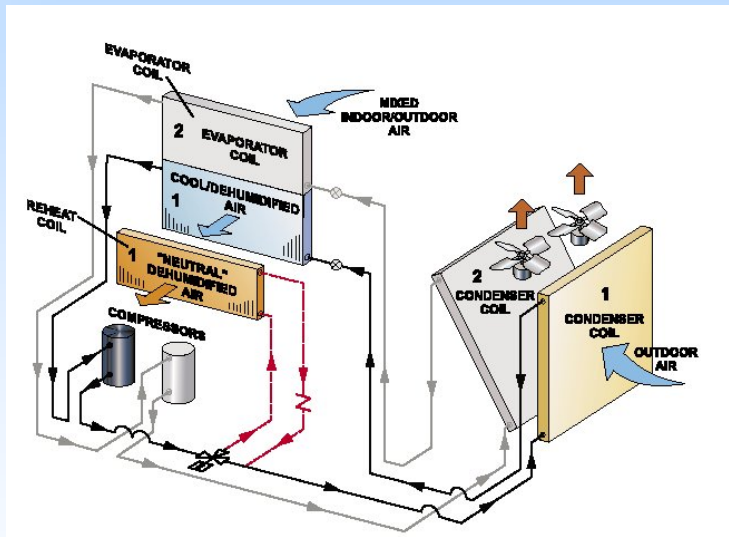
- Lower supply air flow rate (400→350 cfm/ton)
- Colder coil temperature (chilled water)
- Reheat supply air (using condenser heat)
- Subcool/reheat refrigeration circuit
- Ventilation Pretreatment

Enhanced AC Concepts

Improving Conventional AC



Sub/Cool Reheat (Carrier Humid-mizer)

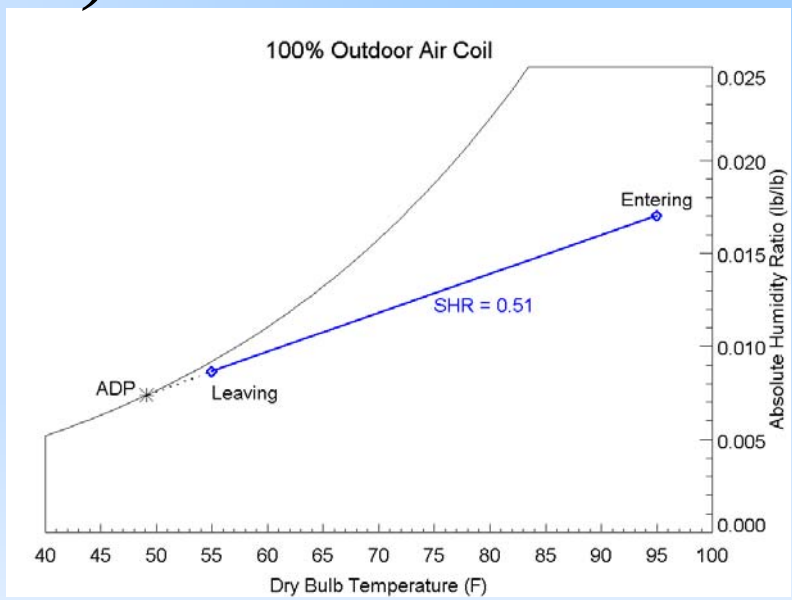


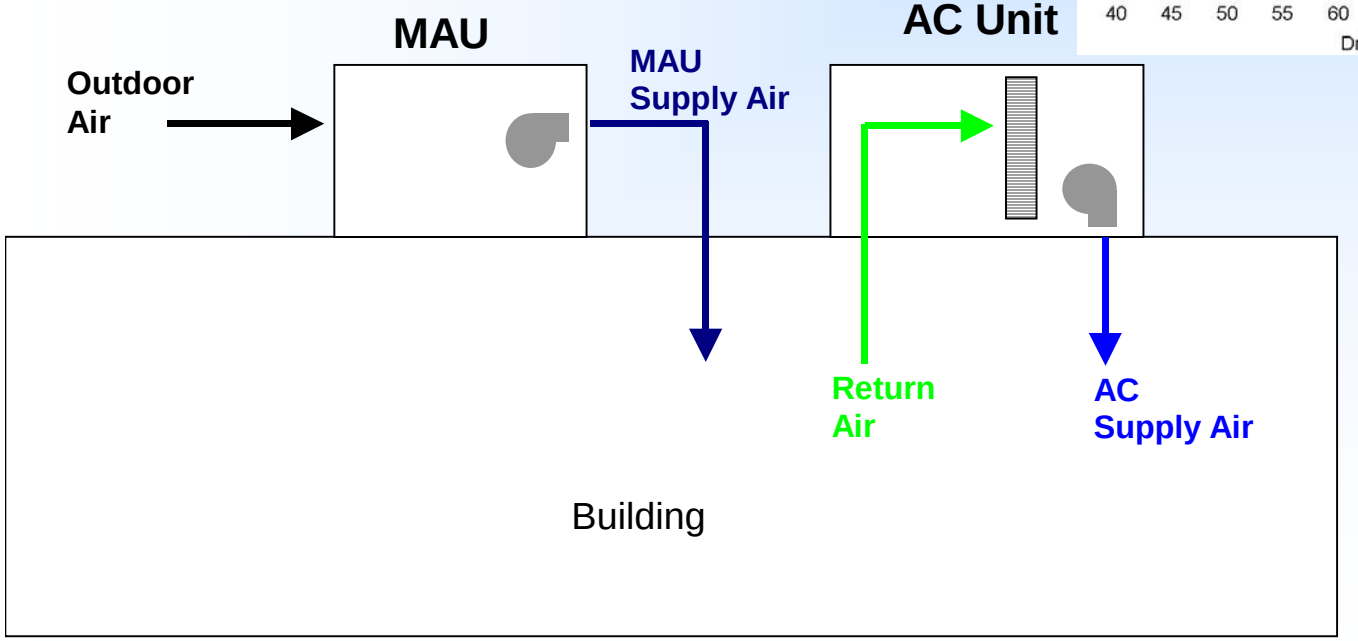
Condenser Reheat (Lennox Humiditrol)

Ventilation Pretreatment

Dedicated Outside Air System (DOAS) or Makeup Air Units (MAU)

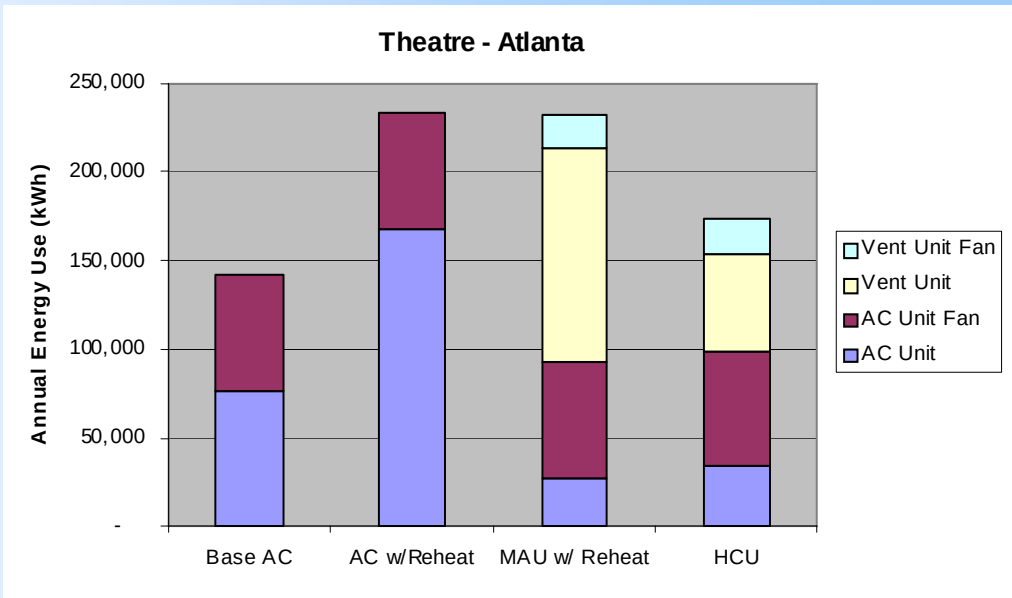
Almost always makes sense!

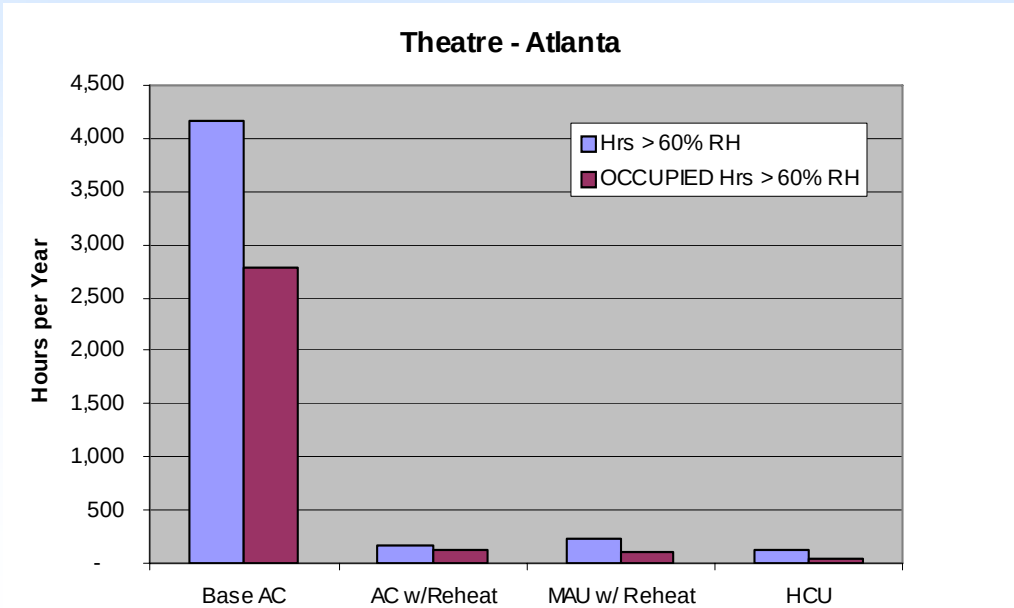




Typical Simulation Results

- *Depends widely on application details*
- *Fan power issues often drive annual results*





ASHRAE Research

1254-RP Report

- Results available for various:
  - Climates
  - equipment types
  - building applications
  - ventilation assumptions

Retail

2001 Standard

Humidity Control (Occupied Hours >65%RH)

Case	System	MI	HO	SH	FW	AT	ST	SL	NY	CH	PO
00	Conventional DX	2384	1636	1169	699	599	455	471	257	233	0
01	Base DX	2279	1519	1066	675	580	438	441	280	226	0
02	DX w/Improved Dehumid.	2361	1653	1153	775	693	519	512	334	261	0
03	Base DX w/Lower Airflow	2273	1573	1082	755	706	514	483	340	266	0
04	Base DX w/AAHX	928	803	542	528	331	289	235	237	157	0
05	Base DX w/Subcool Reheat	1896	1167	777	454	373	281	312	203	179	0
06	Base DX w/o Lat. Coil Degrad.	1341	657	406	99	55	95	133	39	31	0
07	Base DX w/Bypass Damper	1958	1233	829	537	417	331	334	238	195	0
08	Base DX w/Desiccant	0	0	0	0	0	0	0	0	0	0
09	Base DX w/Enthalpy Wheel	19	5	14	1	5	4	1	2	0	0
10	Base DX w/OA Precool	2337	1724	1294	1180	794	620	730	260	217	0
11	Dual Path	653	252	78	38	13	25	2	18	6	0
12	Dual Path w/Enthalpy Wheel	4	5	11	0	5	0	0	0	0	0
13	Dual Path w/AAHX	241	169	53	19	6	0	2	6	3	0
14	Dual Path w/Desiccant	0	0	0	0	0	0	0	0	0	0
15	Base DX w/DCV	2279	1519	1066	675	580	438	441	280	226	0
16	Dual Path w/DCV	653	252	78	38	13	25	2	18	6	0
17	Base DX w/Free Reheat	3	12	10	2	0	0	1	4	0	0

Relative Annual HVAC Energy Cost vs. Base DX (Case 1)

Case	System	MI	HO	SH	FW	AT	ST	SL	NY	CH	PO
00	Conventional DX	-1%	0%	0%	-1%	0%	0%	0%	1%	0%	1%
01	Base DX	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
02	DX w/Improved Dehumid.	-12%	-12%	-11%	-13%	-10%	-7%	-7%	-11%	-7%	-8%
03	Base DX w/Lower Airflow	-9%	-9%	-8%	-10%	-7%	-5%	-5%	-9%	-5%	-6%
04	Base DX w/AAHX	24%	21%	18%	18%	13%	9%	9%	12%	8%	9%
05	Base DX w/Subcool Reheat	12%	11%	9%	10%	7%	5%	5%	6%	4%	4%
06	Base DX w/o Lat. Coil Degrad.	7%	6%	5%	6%	5%	3%	3%	4%	3%	2%
07	Base DX w/Bypass Damper	3%	3%	2%	2%	1%	1%	1%	1%	1%	0%
08	Base DX w/Desiccant	181%	84%	79%	50%	65%	18%	15%	7%	-11%	-3%
09	Base DX w/Enthalpy Wheel	-27%	-30%	-30%	-31%	-30%	-43%	-47%	-32%	-46%	-18%
10	Base DX w/OA Precool	8%	6%	6%	3%	7%	6%	5%	8%	7%	8%
11	Dual Path	-26%	-22%	-20%	-20%	-19%	-13%	-13%	-21%	-14%	-18%
12	Dual Path w/Enthalpy Wheel	-40%	-43%	-41%	-42%	-41%	-51%	-55%	-44%	-55%	-28%
13	Dual Path w/AAHX	0%	-1%	-2%	-1%	-5%	-4%	-3%	-10%	-6%	-11%
14	Dual Path w/Desiccant	151%	60%	51%	24%	27%	-6%	-8%	-13%	-29%	-14%
15	Base DX w/DCV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16	Dual Path w/DCV	-26%	-22%	-20%	-20%	-19%	-13%	-13%	-21%	-14%	-18%
17	Base DX w/Free Reheat	54%	40%	29%	27%	19%	12%	13%	12%	9%	1%

Occupied Hours >65%RH

- <= 150 hrs
- 151 to 1000 hrs
- 1001 to 2000 hrs
- > 2000 hrs

% Change in Annual HVAC Energy Cost

- < 0% (less energy use)
- 1% to 25% (more energy use)
- 26% to 50% (more energy use)
- >50% (more energy use)

Criteria	Best Cases (Case ID Number)									
Minimum Energy Cost (EC)	12	12	12	12	12	12	12	12	12	12
Minimum EC, <=150 hrs RH>65%	12	12	12	12	12	12	12	12	12	12
Minimum Life Cycle Cost (LCC)	12	12	12	12	09	09	09	12	09	09
Minimum LCC, <=150 hrs RH>65%	12	12	12	12	09	09	09	12	09	09
Ratio Min LCC<=150 to Case 01 LCC	0.8	0.8	0.7	0.7	0.8	0.7	0.7	0.8	0.7	0.9

MI	=	Miami FL	ST	=	Washington DC
HO	=	Houston TX	SL	=	St. Louis MO
SH	=	Shreveport LA	NY	=	New York NY
FW	=	Fort Worth TX	CH	=	Chicago IL
AT	=	Atlanta GA	PO	=	Portland OR

Summary

- Wide Spectrum of Dehumidification Technologies are Available
  - Best solution depends on building application details
  - Equipment configuration and controls also maters
- Hybrid Technologies look promising
- Ventilation pre-treatment is almost always a good idea in commercial applications