

Emerging Technologies Report

Dehumidification Enhancements for Air Conditioners in Hot-Humid Climates

April, 2009

Definition	Packaged air conditioners in hot-humid climates with the dehumidification enhancement feature				
Base Case	5-ton rooftop unit				
New Measure:	Incorporation of a Cromer cycle dehumidification feature	Percent savings	2025 Savings TBtu (Source)	Cost of Saved Energy	Success Rating (1-5)
		30%	49	\$0.00/kWh	3

Summary

Space conditioning in commercial buildings in hot-humid climates requires introducing large amounts of humid outdoor air to meet ventilation standards for indoor air quality.¹ The combined humidity and sensible loads can be beyond the ability of conventional vapor compression air conditioners to provide thermal comfort and protect the building. The Cromer cycle is a novel combination of a desiccant wheel and a vapor compression air conditioner. It is now commercially available.

Cromer Cycle HVAC systems can match building loads in humid areas better, especially at part-load conditions, and reduce the need for reheat. They can also allow smaller capacity cooling equipment to be used. Cromer cycle technology can produce supply air that has a dew point 0-10°F below the temperature of the refrigerant in the cooling coil, while a typical cooling coil can only dehumidify air to a dew point 5-10°F above the temperature of the refrigerant². Manufacturer's literature estimates that for humidity-sensitive applications, a high-efficiency rooftop unit with the Cromer cycle can allow downsizing of equipment by 15-33%, improve the latent capacity by 40-160%, lower the dew point of the supply air by 2-5°F, reduce cooling energy by 10-30%, and reduce reheat and total energy by 30–90%.

Background and Description

Buildings in hot and humid climate conditions often require large amounts of air conditioning for achieve comfort, which includes both temperature and humidity. In the US, the hot and humid climate zone³ (see Figure 1) includes the southeast zone from eastern Texas to Florida and southern Georgia, as well as Puerto Rico and Hawaii.

¹ Kosar, D., "Dehumidification System Enhancements", *ASHRAE Journal* Vol 48 Feb 2006, pg. 48-58

² Trane Engineering Bulletin "Trane CDQ Desiccant Dehumidification"

³ http://www1.eere.energy.gov/buildings/residential/climate_zones.html

Map of DOE's Proposed Climate Zones

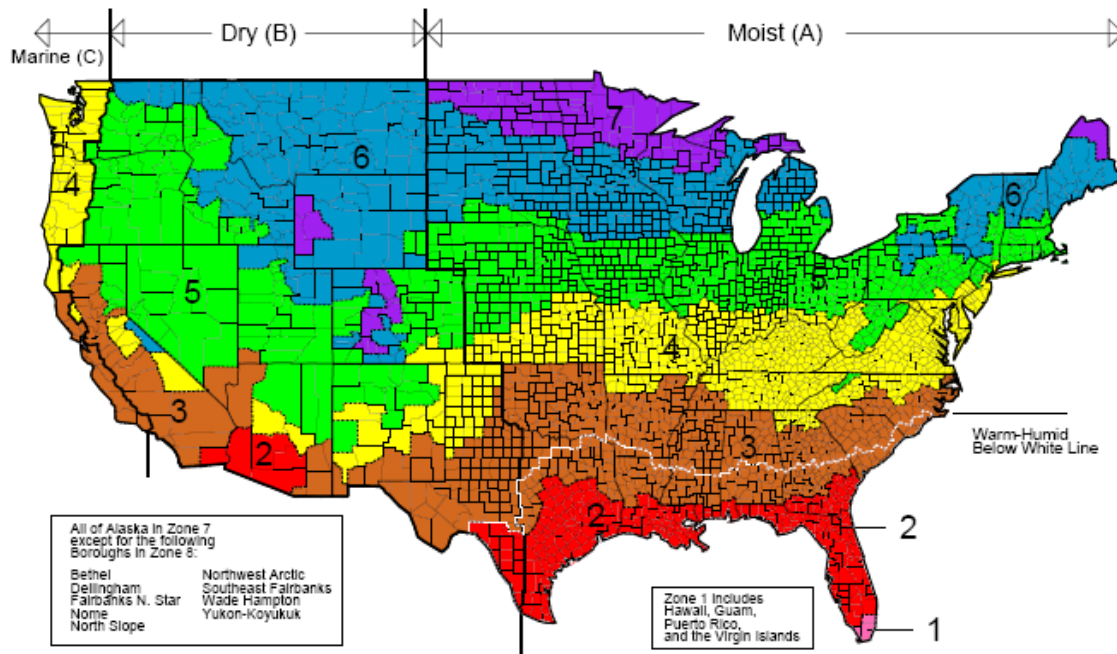


Figure 1: Climate zones of the US⁴

Notes: Hot-humid is Southeast, from GA-SC border at Atlantic through the coastal plain of Texas. Warm-humid extends from Delaware through the SE States, Arkansas, most of Oklahoma and Texas, and parts of the SW.

Internal gains and the intense solar radiation in the zone justify cooling. The humidity of the air also needs to be controlled, as high humidity is uncomfortable and could lead to mold and condensation problems, which could in turn impact occupant health and the structure. Overly high humidity can also result in higher cooling demand, as occupants reduce thermostat settings to achieve greater comfort. Generally, relative humidity needs to be kept to below 60%.

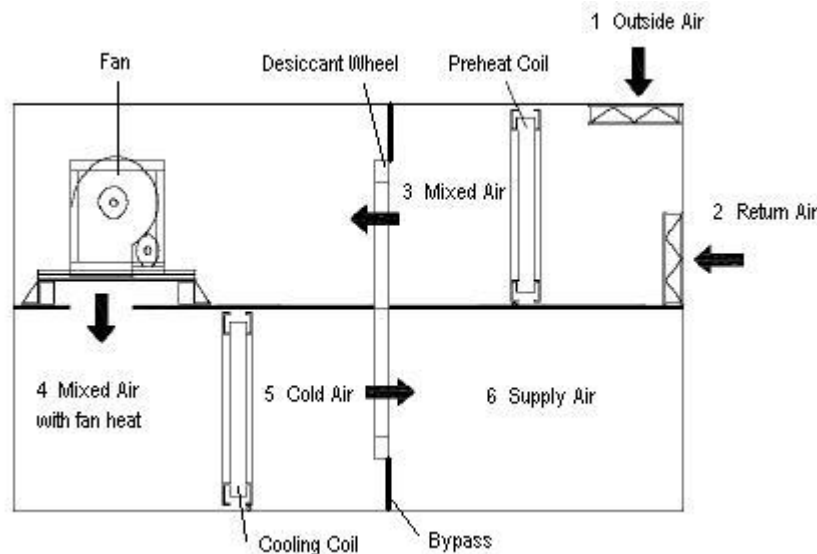
Air conditioning requires controlling both *sensible* heat (temperature measured by a thermometer) and *latent* heat (the water vapor in the air). During the past decades, building standards (e.g., ASHRAE 90.1) have become more stringent, reducing envelope, lighting, and equipment loads, and thus sensible heat requirements. But, more ventilation is required by ASHRAE 62.1, the standard for ventilation for indoor air quality. Because ventilation loads are increasing, relative latent loads are also increasing, because ventilation air is usually a much larger source of water vapor than any internal source such as respiration by occupants.

Although simple vapor compression air conditioners adapt by removing more humidity when latent loads are higher, they have clear limits, so there can be a mismatch between the normal sensible heat ratio of unitary air conditioners and that needed to condition the building in humid conditions.⁵ Indeed, with conventional equipment, reducing humidity may require overcooling (to remove water vapor) and then reheating the air to a comfortable temperature. ASHRAE 90.1, the Energy Standard, strongly discourages reheat.

⁴ http://www.energycodes.gov/implement/pdfs/color_map_climate_zones_Mar03.pdf

⁵ TIAX LLC, "Matching the Sensible Heat Ratio of Air Conditioning Equipment with the Building Load SHR", Nov 12 2003, Pg 2-13

The Cromer cycle is a novel approach that positions a desiccant wheel across the supply air stream both before and after the cooling coils.



The Cromer Cycle (adapted from Trane literature)

With the Cromer Cycle, outside ventilation air (1) is mixed with return air from the space (2). The mixed air (3) may be preheated to increase evaporation from the wheel. The mixed air then passes across the desiccant wheel, which is relatively moist since it has just passed through the more humid cold air (5). The desiccant wheel thus releases moisture into the mixed air, raising its relative humidity.

The more humid mixed air is then blown across a cooling coil, generating cold, saturated air, since cold air can hold less moisture than warm air. Thus, water vapor condenses on the cooling coil and drains from the air conditioner (5). Some of the remaining moisture is then absorbed by the desiccant wheel, and the dehumidified air (6) is then supplied to the building area.

By moving moisture from the cold air (5) to the mixed air (3) using the desiccant wheel, as well as heating the mixed air using preheating and fan heat, the air passing across the cooling coil is both warmer and more humid. This increases the amount of moisture the cooling coil can remove from the air, enhancing the latent capacity of the cooling coil and lowering the dew point of the supply air.

Thus, Cromer cycle HVAC systems can match building loads in humid areas better, especially at part-load conditions. It can also allow smaller capacity cooling equipment to be used. Cromer cycle technology can produce supply air that has a dew point 0-10°F below the temperature of the refrigerant in the cooling coil, while a typical cooling coil can only dehumidify air to a dew point 5-10°F above the temperature of the refrigerant.⁶ A manufacturer estimates that for humidity-sensitive applications, a high-efficiency rooftop unit with the Cromer Cycle can allow downsizing of equipment by 15-33%, improve latent capacity by 40-160%, lower the dew point of the supply air by 2-5°F, reduce cooling energy by 10-30%, and reduce reheat and total energy by 30-90%.⁷ In addition, the Cromer cycle is applicable to chiller-based systems.⁸

⁶ Trane Engineering Bulletin "Trane CDQ Desiccant Dehumidification"

⁷ Trane, "CDQ Dehumidification with Trane Rooftop Units", CDQ-SLB001-EN

⁸ Trane, "CDQ Dehumidification with Climate Changer Air Handlers", CDQ-SLB002-EN

Data Summary

Market Sector	Market Application		End Use	Fuel Type
Commercial	New/Replace on Burnout Long Life		Cooling	Electricity
Current Status	Date of Com		Product Life (years)	Source
Commercialized			15	Trane
Basecase Energy Use		Units	Notes, Explanation	Source
Efficiency	10	EER	Federal mandated energy efficiency, from 2010	
Electricity Use	9000	kWh/yr	Using FEMP energy cost calculator	FEMP
Summer Peak Demand	6	kW	5 ton, 10 EER (5*12/10)	
Winter Peak Demand	0	kW		
Fuel Use		MMBtu/year		
New Measure Energy Use				
Efficiency	11.4	EER	Using FEMP energy cost calculator and estimated annual electricity use (see below)	FEMP
Electricity Use	6300	kWh/yr	Assuming 30% electricity use reduction, based on lower end of range of estimates for total energy reduction in literature	
Summer Peak Demand	4.2	kW	4 ton, 11.4 EER (4*12/11.4)	
Winter Peak Demand		kW		
Fuel Use		MMBtu/yr		
Savings				
Electricity Savings	2700	kWh/year		
Summer Peak Demand Svgs	1.8	kW		
Winter Peak Demand Svgs		kW		
Fuel Savings		MMBtu/year		
Percent Savings	30%			
Percent Feasible	9%		Assuming population of counties is a proxy of commercial building distribution, some 17.7% of commercial buildings are in warm-humid climates; Assume 50% uptake	
Industrial Savings > 25%?	no			
Costs				
Incremental Cost	350	2009\$	150% of cost of adding energy wheel,	
Other Costs/ (Savings)	-40	\$/ year	Estimated first cost reduction for reduced size of RTU, using RS Means 2009, depreciated across 15yr lifespan	

Ranking Metrics			
2025 Savings Potential	4700	GWh	
2025 Savings Potential	49	TBtu	
Cost of Saved Energy	0.00	\$/kWh	
Cost of Saved Energy		\$/MMBtu	
Unusual Market Barriers	Non-Energy Benefits		Next Steps
Contractor/Builder Training	Cleaner boiler operations Longer boiler life Increased occupant comfort		Advertising Incentives Field Testing Strategic Marketing
Likelihood of Success	3	(1-5)	
Priority	Medium	Low, Med, High	
Data Quality Assessment	B	(A-D)	
Principal Contacts			
Charles Cromer, Florida Solar Energy Center			
Ronnie Moffitt, Trane Corporation.			

Current Status of Measure

The Cromer Cycle has been commercialized by Trane under the trade name “CDQ”. The product, introduced in 2005, was named the “2006 HVAC Dehumidification Systems Product of the Year” by research and consulting firm Frost & Sullivan⁹.

The CDQ is currently being targeted at niche market segments which require significant humidity control, such as hospitals, museums, and storage. It is also being applied in LEED-type projects to improve the energy efficiency of DOAS¹⁰.

Energy Savings and Costs

Literature from Trane estimates that for humidity-sensitive applications, a high-efficiency rooftop unit with the Cromer Cycle can allow downsizing of equipment by 15-33%, improve the latent capacity by 40-160%, reduce cooling energy by 10-30%, and reduce reheat and total energy by 30-90%.

In a 2005 field test in Florida, a 3-ton prototype Cromer Cycle rooftop unit was run side by side with a standard 3-ton unit with a reheat coil. The result of the field test was that the prototype saved 75.7% of electricity consumption even though it was delivering cooler air at a lower relative humidity.¹¹

Simulations were also run on Trane software to compare various energy recovery options with a dedicated outdoor air system (DOAS):

- Cool-reheat system (no energy recovery)
- Cool-reheat system (with energy recovery using an energy wheel)
- Cool-reheat system (with heat recovery using an air-to-air heat exchanger)
- Using an energy wheel to pre-condition the outdoor air and the CDQ for additional dehumidification

⁹ <http://www.trane.com/Commercial/Uploads/PDF/1254/traneIND06.pdf>

¹⁰ Email correspondence with Ronnie Moffitt, Trane Corporation

¹¹ C. Cromer, “Field Test of Combined Desiccant-Evaporator Cycle Providing Lower Dew Points and Enhanced Dehumidification”

The simulations were based on the scenario of a 100,000 sf office building utilizing a DOAS system that delivers 10,000 cfm of ventilation air at 58°F, 47 gr/lbm, 46.6°F dew point conditions.

At design day conditions of 99.4°F and 109.4 gr/lbm outdoor air,

OPTION	COOLING REQUIRED (Tons)	CHILLER CAPACITY (kW)	REHEAT ENERGY REQUIRED (Btu/hr)	CHILLER CAPACITY REDUCTION
Cool-Reheat	85.1	111.2	102000	-
Cool-Reheat with Energy Wheel	55.4	72.4	102000	35%
Cool-Reheat with Heat Exchanger	71.8	93.8	102000	16%
Energy Wheel and CDQ	51.2	61.5		45%

At design day conditions of 83.0°F and 130 gr/lbm outdoor air,

OPTION	COOLING REQUIRED (Tons)	CHILLER CAPACITY (kW)	REHEAT ENERGY REQUIRED (Btu/hr)	CHILLER CAPACITY REDUCTION
Cool-Reheat	81.8	84.0	102000	-
Cool-Reheat with Energy Wheel	55.7	57.2	102000	32%
Cool-Reheat with Heat Exchanger	76.8	78.9	102000	6%
Energy Wheel and CDQ	50.6	48.3		42%

The integration of a CDQ with an energy wheel into a DOAS system can result in significantly reduced chiller capacity requirements, potentially generating significant first cost savings since a smaller chiller system can be used.

Key Assumptions used in Analysis

Average Price of Electricity	\$0.1032/kWh ¹²
Average Price of Natural Gas	\$10.97/MMBtu ¹³
Real Discount Rate	4.53%
Projected 2025 End Use Gas Consumption (EIA 2009) ¹⁴	1.25 quads
Heat Rate	10.48 kBtu/kWh

¹² EIA, "Electric Power Monthly – Feb 2009", (YTD-Nov08, Commercial Price)

¹³ http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_nus_m.htm

¹⁴ EIA 2009. "Annual Energy Outlook 2009 with Projections to 2030". Tables 4 and 5.

Recommended Next Steps

Good case studies by third parties will establish a basis for system performance comparisons, expanding the market and forcing innovation by competitors. LEED consideration of enhanced humidity control in humid regions would help, too.