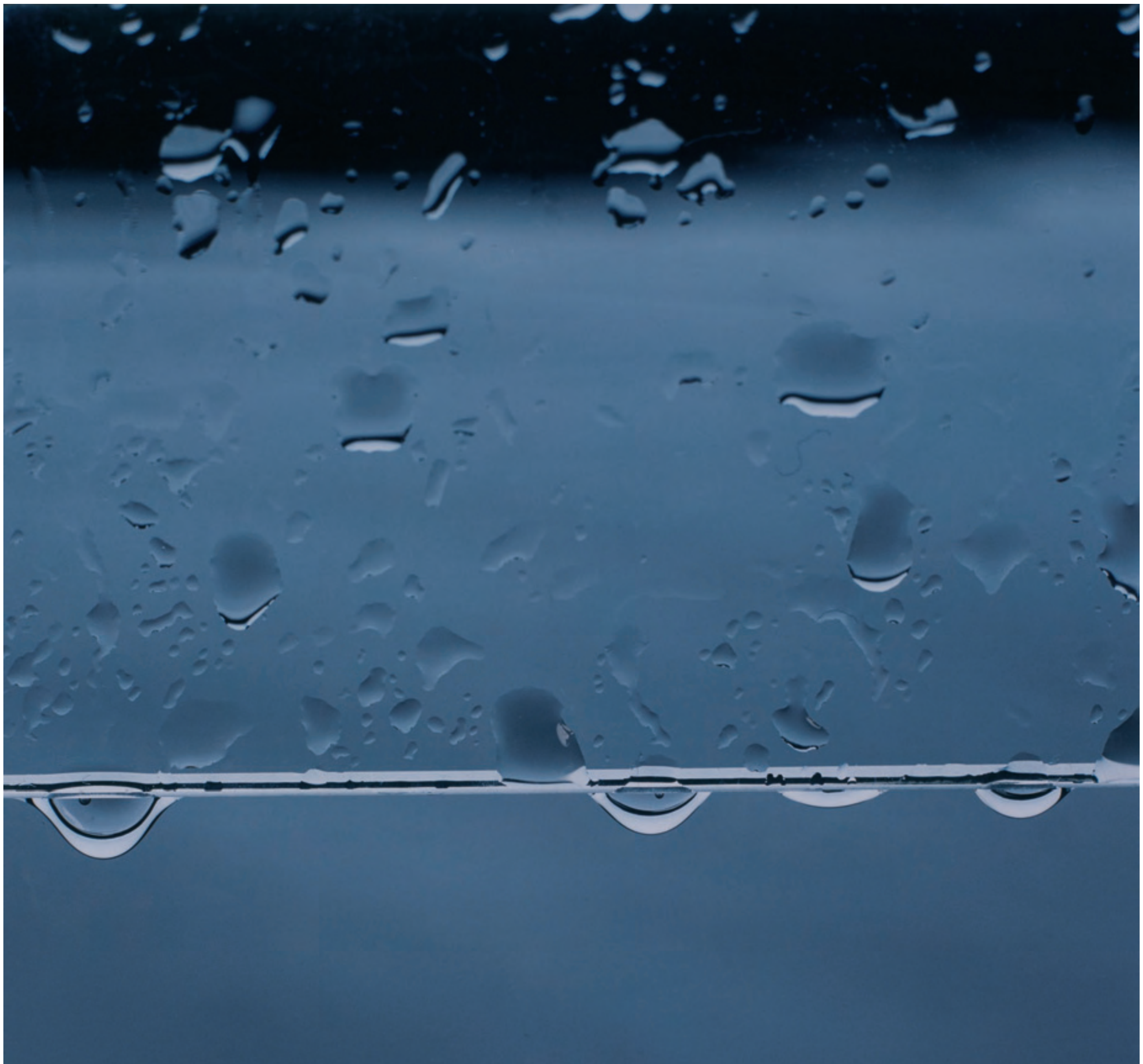
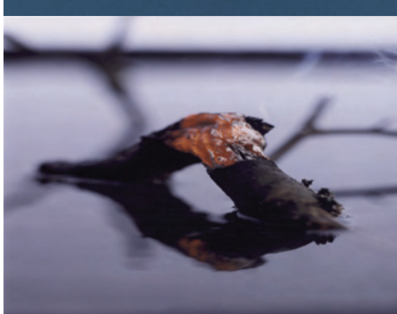


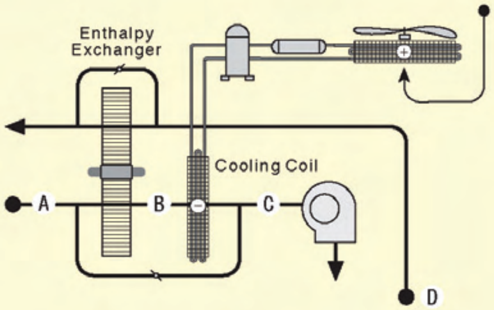


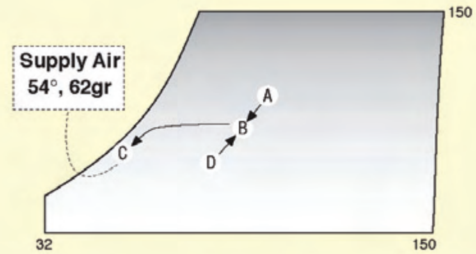
How the HCU exceeds ASHRAE STD 90.1 Sect 6.5.6.1 - Exhaust Air Energy Recovery

Munters

The Humidity Expert

Baseline System
Coil assisted by exhaust air energy recovery

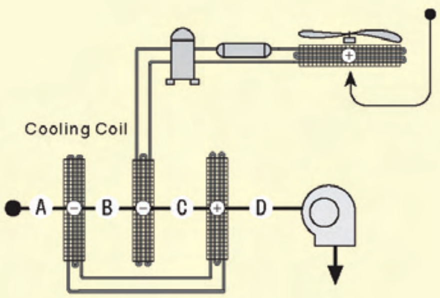


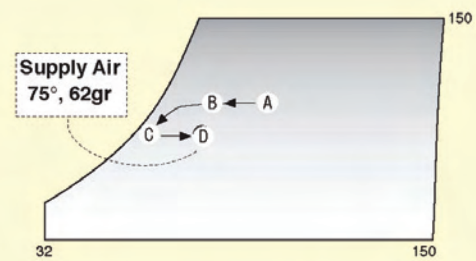


	A	B	C	D
Air Flow (scfm)	3,500	3,500	3,500	3500
Temperature (°F)	75	75	54	75
Moisture (gr/lb)	102	83	62	65
Enthalpy (Btu/lb)	33.95	30.98	22.61	28.16

Coil Work (Btu/lb) = 8.37

Exception (i)
Coil assisted by heat exchanger using site-recovered energy

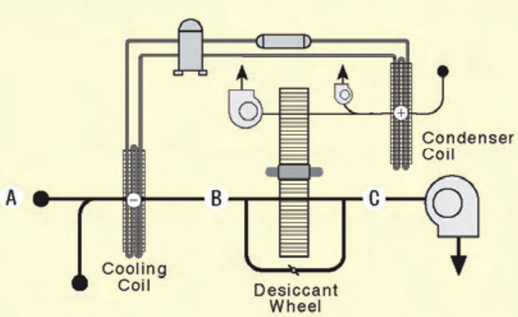


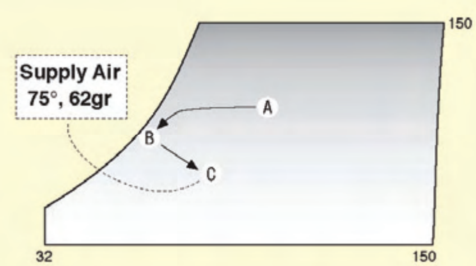


	A	B	C	D
Air Flow (scfm)	3,500	3,500	3,500	3500
Temperature (°F)	75	68	54	75
Moisture (gr/lb)	102	102	62	62
Enthalpy (Btu/lb)	33.95	32.22	22.61	28.16

Coil Work (Btu/lb) = 9.61

Proposed Exception
Coil assisted by desiccant using site-recovered energy





	A	B	C
Air Flow (scfm)	3,500	3,500	3,500
Temperature (°F)	75	61	75
Moisture (gr/lb)	102	80	62
Ending Enthalpy (Btu/lb)	33.95	27.15	27.69

Coil Work (Btu/lb) 6.80

ASHRAE STD 90.1 PARAGRAPH 6.5.6.1 READS:

"Exhaust air energy recovery. Individual fan systems that have both a design supply air capacity of 5,000 cfm or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% energy recovery effectiveness." (The paragraph continues, supplying definitions and the requirement to bypass the heat recovery system during economizer operation)

Further in this section, an exception to these requirements is allowed for systems which require dehumidification. Specifically, subparagraph 6.5.6.1.i has exempted: "Systems requiring dehumidification that employ energy recovery in series with the cooling coil."

REASONS AND SUBSTANTIATION WHY THE HCU EXCEEDS ASHRAE STD 90

Section 6.5.6.1 ensures that whenever a system brings large amounts of outdoor air into a building, energy recovery equipment is in-place to minimize the energy required to heat or cool the incoming air.

At the same time, this section recognizes that different guidelines are needed when a system requires dehumidification. In those cases, exception (i) allows the use of energy recovery *not* from exhaust air, but rather from the waste heat of the incoming air stream itself. Figure 1 shows the series-configured heat recovery system allowed by exception (i).

The Munters HCU applies to that same situation: systems which require dehumidification, in which the energy for dehumidification can be recovered from within the system itself, without the parasitic effect of an overheated supply air stream.

The Munters HCU is exceptionally energy-efficient. On an annual basis, the system dries the air using 15 to 35% less energy than the exhaust air energy recovery system mandated by Section 6.5.6.1. It also uses 15 to 40% less energy than the dehumidification system allowed under exception (i).

Given that the intent of Std 90 is to reduce *annual* energy consumption, the HCU allows engineers to easily comply and exceed conditions of ASHRAE STD 90. Since the following demonstrates how the HCU exceeds STD 90, the HCU can be used to allow engineers to qualify for additional LEED points relating to increased building design efficiency.

DESICCANT DEHUMIDIFICATION USING CONDENSER HEAT FOR REACTIVATION

Desiccant dehumidifiers now serving more than 500 commercial and institutional buildings use site-recovered heat to reactivate (dry) the desiccant. They get this heat from the condenser section of an internal DX cooling system which pre-cools the air, as shown in figure 1. In this configuration, the desiccant system:

1. Removes moisture at a rate of 0.136 kw/lb/h including fans (Harriman & Judge, Dehumidification Equipment Advances, ASHRAE Journal March 2002, pp. 22-29).
2. Delivers air at, or slightly below the temperature set point of the conditioned space.

LESS ANNUAL ENERGY THAN COOLING COIL ASSISTED BY HEAT RECOVERY

From first appearances, it's not obvious why the Munters HCU could use less energy for dehumidification than the combination of an enthalpy heat exchanger and a cooling coil. But on examination, the reasons for this fact become clear.

The key difference is that the desiccant-assisted cooling coil is much more efficient for dehumidification than the baseline system, *when moderate outdoor air temperatures combine with high moisture levels*. These conditions occur for thousands of hours per year in all climate regions. As a consequence, on an annual basis, the desiccant-assisted coil uses less energy to do the same work as the same coil when assisted by an exhaust-air energy recovery system. The desiccant-assisted coil simply does not have to do as much work, because the desiccant component removes a great deal of the moisture.

The charts in figures 2, 3, 4 and 5 report the annual energy comparisons between the baseline system and our proposed exception.

The analysis assumes that both systems must deliver outdoor air to the building at a neutral moisture level (75°F, 50% rh, 28.01 Btu/lb, 55°F dpt, 65 gr/lb). A second assumption is that, because dehumidification is required, both systems must dry the incoming air any time the outdoor air is more humid than the building-neutral moisture level.

Note that at the extreme design condition, the exhaust recovery-assisted coil performs admirably, while the desiccant-assisted coil is at a disadvantage. However, those conditions, by definition, only occur for 35 to 175 hours every year. Shortly, as the outdoor temperature falls and the outdoor humidity rises, the desiccant-assisted coil becomes much more energy-efficient than the baseline system. This is because the deep-drying capability of the desiccant relieves its cooling coil of the need to chill the air deeply to provide dehumidification down to the building-neutral level.

Consider the changes in enthalpy shown in figure 1 for the baseline coil vs. the desiccant-assisted coil. Note that when air is entering from the weather at 75°F and 102 gr/lb, the coil in the baseline system must reduce the enthalpy by 8.37 Btu/lb.

Compare that work to the enthalpy reduction required of the coil in the desiccant alternative. Because the desiccant component can dry the air deeply, the cooling coil only needs to reduce the enthalpy of the incoming air by 6.80 Btu/lb. The desiccant component accomplishes the remaining dehumidification. Since the coil in the desiccant system can do less work, the cooling equipment in that system uses less energy during those hours.

The spreadsheets show the energy saved when these differences are calculated for all of the hours when the outdoor humidity is above the condition required inside the building. Please note from the last column in these spreadsheets, that the baseline system has an advantage (uses less energy) until the outdoor enthalpy declines to about 37 Btu/lb. As the outdoor enthalpy goes below that value, the desiccant-assisted coil picks up advantages. Because there are *so many hours* below that enthalpy in all locations, the net effect is that the desiccant-assisted coil uses considerably less energy each year than the baseline system from section 6.5.6.1.

HCU V. OTHER DESICCANT DEHUMIDIFICATION CONFIGURATIONS

Not all desiccant systems exceed the efficiency of the base energy recovery systems. Many are suited only to the deep-drying of specialty low-dew point applications where their higher-than usual energy requirements are justified by user benefits.

When using the HCU in lieu of energy recovery systems engineers need to consider the following:

1. "Systems requiring dehumidification..." The HCU is when used in system designs that require humidity control.

2. "...in which the reactivation energy is entirely site-recovered..." The HCU recaptures all of its reactivation energy from the condenser coil resulting in extremely efficient operation.

2. "...and which does not deliver the supply air above the space design temperature." Finally, the HCU is designed to deliver air well within the ASHRAE defined comfort zone as it relates to temperature and does not add a sensible cooling load to the space.

SUMMARY

The Munters HCU would allow building owners to comply with std 90, while continuously using the most energy-efficient means of removing large amounts of moisture from air. The HCU has been proven in use over the last four years on the rooftops of more than 500 buildings across the US.

Building owners and society as a whole would benefit by using the HCU to reduce the energy needed to accomplish dehumidification. Denying the use of the HCU would discourage the energy-efficient innovation that std 90 is intended to promote.

References

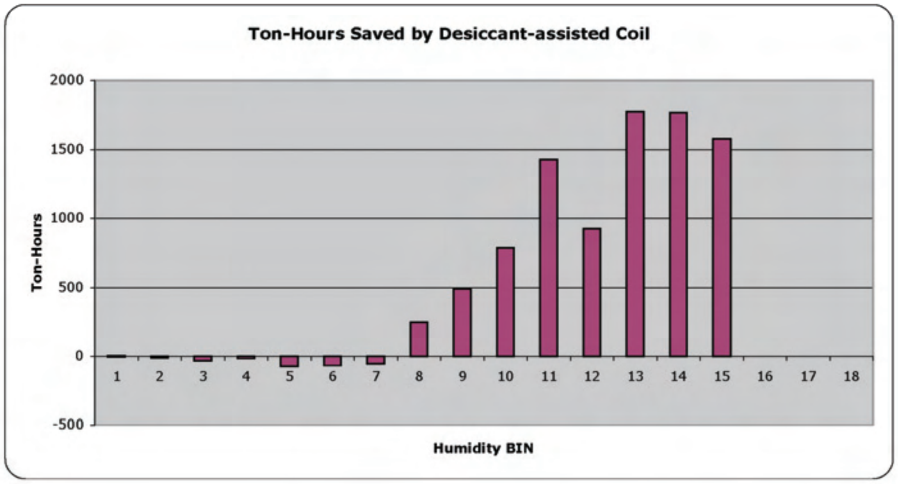
1) *ASHRAE standard 90.1 Section 6.5.6.1 - Exhaust air energy recovery*

2) *Harriman & Judge, Dehumidification Equipment Advances, ASHRAE Journal March 2002, pp. 22-29*

Savings Estimate for Atlanta

Atlanta Weather (5 gr Humidity BINs) HR (gr/lb)	MCDB (°F)	h (Btu/lb)	Hours	Exhaust Recovery System (Baseline) h (Entering Coil)	Coil Work (Δh)	Ton-Hours	Desiccant Coil Work (Δh)	Desiccant Saving (or cost) Tons	Ton-Hours	%
147.5	83.0	43.1	2	35.56	12.95	34.0	15.95	(3.94)	(7.9)	-18.8%
142.5	83.3	42.3	3	35.16	12.55	49.4	15.15	(3.42)	(10.3)	-17.2%
137.5	83.1	41.5	12	34.76	12.15	191.3	14.35	(2.89)	(34.7)	-15.4%
132.5	83.8	40.9	8	34.46	11.85	124.4	13.75	(2.50)	(20.0)	-13.9%
127.5	80.8	39.4	48	33.71	11.10	699.0	12.25	(1.52)	(72.8)	-9.4%
122.5	80.0	38.4	82	33.21	10.60	1140.3	11.25	(0.86)	(70.5)	-5.8%
117.5	79.5	37.5	204	32.76	10.15	2716.3	10.35	(0.27)	(54.9)	-2.0%
112.5	77.7	36.2	424	32.11	9.50	5284.0	9.05	0.58	247.6	4.9%
107.5	75.7	35.0	358	31.51	8.90	4179.5	7.85	1.37	491.0	13.3%
102.5	74.8	34.0	387	31.01	8.40	4264.1	6.85	2.03	784.8	22.6%
97.5	73.1	32.8	508	30.41	7.80	5197.3	5.65	2.82	1430.2	38.0%
92.5	73.3	32.0	277	30.01	7.40	2688.5	4.85	3.34	925.3	52.5%
87.5	72.1	31.0	445	29.51	6.90	4027.1	3.85	4.00	1778.5	79.1%
82.5	70.8	29.9	375	28.96	6.35	3122.9	2.75	4.72	1769.4	130.7%
77.5	70.0	28.9	294	28.46	5.85	2255.4	1.75	5.37	1580.2	234.0%
Total dehumidification hours			**3427**	**Baseline ton-hours**		**35973.6**	**Annual Savings**		**8735.9**	**24.3%**

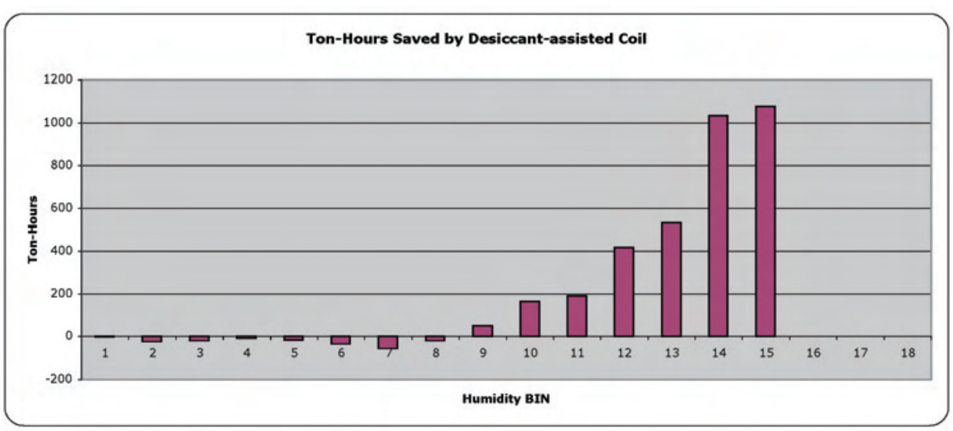
Assumptions	
Supply airflow	3500
Space DB	75
Space HR	65
Space enthalpy	28.01
Exchanger Effectiveness	0.5
Enthalpy leaving baseline coil	22.61
Enthalpy leaving desiccant coil	27.15



Savings Estimate for Chicago

Chicago Weather (5 gr Humidity BINs) HR (gr/lb)	MCDB (°F)	h (Btu/lb)	Hours	Exhaust Recovery System (Baseline) h (Entering Coil)	Coil Work (Δh)	Ton-Hours	Desiccant Coil Work (Δh)	Desiccant Saving (or cost) Tons	Ton-Hours	%
152.5	82.0	43.6	1	35.81	13.20	17.3	16.45	(4.27)	(4.3)	-19.8%
147.5	85.3	43.6	6	35.81	13.20	103.9	16.45	(4.27)	(25.6)	-19.8%
142.5	84.8	42.7	6	35.36	12.75	100.4	15.55	(3.68)	(22.1)	-18.0%
137.5	80.3	40.8	4	34.41	11.80	61.9	13.65	(2.43)	(9.7)	-13.6%
132.5	82.4	40.5	8	34.26	11.65	122.3	13.35	(2.24)	(17.9)	-12.8%
127.5	82.0	39.7	21	33.86	11.25	309.9	12.55	(1.71)	(36.0)	-10.4%
122.5	83.1	39.2	42	33.61	11.00	606.1	12.05	(1.38)	(58.2)	-8.8%
117.5	81.5	38.0	37	33.01	10.40	504.8	10.85	(0.60)	(22.1)	-4.2%
112.5	77.3	36.2	86	32.11	9.50	1071.7	9.05	0.58	50.2	4.9%
107.5	76.6	35.2	132	31.61	9.00	1558.4	8.05	1.24	163.7	11.7%
102.5	75.2	34.1	98	31.06	8.45	1086.2	6.95	1.96	192.3	21.5%
97.5	75.2	33.3	168	30.66	8.05	1773.9	6.15	2.49	417.8	30.8%
92.5	75.1	32.5	177	30.26	7.65	1776.0	5.35	3.01	533.2	42.9%
87.5	72.6	31.1	263	29.56	6.95	2397.3	3.95	3.93	1033.8	75.8%
82.5	71.7	30.1	235	29.06	6.45	1987.9	2.95	4.59	1078.0	118.5%
77.5	70.2	28.9	396	28.46	5.85	3037.9	1.75	5.37	2128.4	234.0%
72.5	69.0	27.9	310	27.96	5.35	2174.7	0.75	6.03	1869.6	612.7%
Total dehumidification hours			**1990**	**Baseline ton-hours**		**18690.9**	**Annual Savings**		**7271.2**	**38.9%**

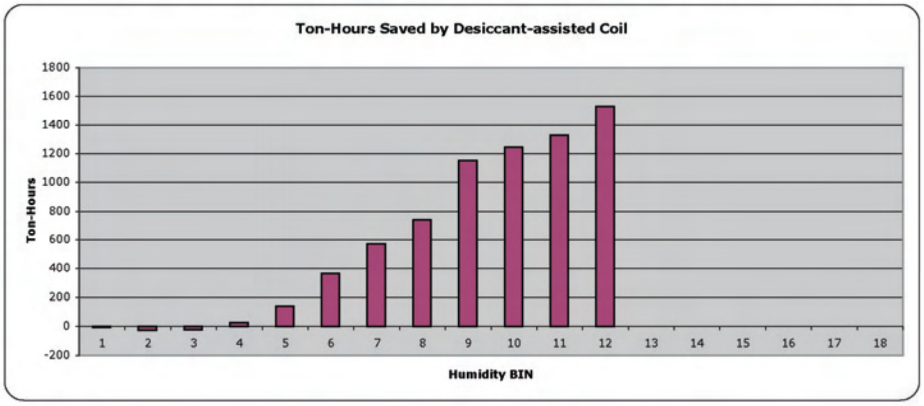
Assumptions	
Supply airflow	3500
Space DB	75
Space HR	65
Space enthalpy	28.01
Exchanger Effectiveness	0.5
Enthalpy leaving baseline coil	22.61
Enthalpy leaving desiccant coil	27.15



Savings Estimate for Newark

Newark Weather (5 gr Humidity BINs)				Exhaust Recovery System (Baseline)			Desiccant	Desiccant Saving (or cost)		
HR (gr/lb)	MCDB (°F)	h (Btu/lb)	Hours	h (Entering Coil)	Coil Work (Δh)	Ton-Hours	Coil Work (Δh)	Tons	Ton-Hours	%
127.5	77.6	38.6	5	33.31	10.70	70.2	11.45	(0.99)	(5.0)	-6.6%
122.5	80.5	38.5	27	33.26	10.65	377.2	11.35	(0.93)	(25.0)	-6.2%
117.5	80.6	37.7	59	32.86	10.25	793.3	10.55	(0.40)	(23.6)	-2.9%
112.5	79.8	36.8	136	32.41	9.80	1748.4	9.65	0.19	25.9	1.5%
107.5	76.5	35.2	111	31.61	9.00	1310.5	8.05	1.24	137.7	11.7%
102.5	76.0	34.3	199	31.16	8.55	2231.8	7.15	1.83	364.4	19.5%
97.5	75.3	33.3	230	30.66	8.05	2428.6	6.15	2.49	572.1	30.8%
92.5	75.1	32.5	246	30.26	7.65	2468.4	5.35	3.01	741.0	42.9%
87.5	72.7	31.1	293	29.56	6.95	2670.8	3.95	3.93	1151.8	75.8%
82.5	72.3	30.2	275	29.11	6.50	2344.3	3.05	4.52	1243.4	113.0%
77.5	71.6	29.3	260	28.66	6.05	2062.9	2.15	5.11	1329.2	181.2%
72.5	71.0	28.4	268	28.21	5.60	1968.0	1.25	5.70	1528.4	347.6%
Total dehumidification hours			**2109**	**Baseline ton-hours**		**20474.4**	**Annual Savings**		**7040.1**	**34.4%**

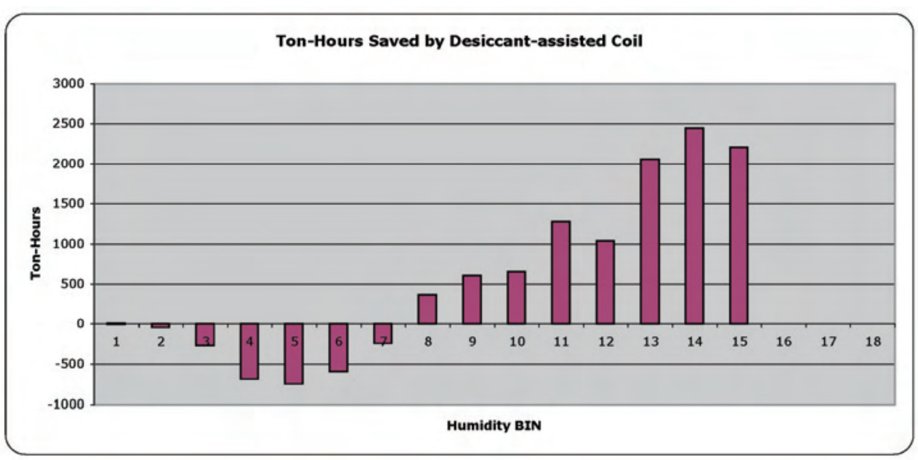
Assumptions	
Supply airflow	3500
Space DB	75
Space HR	65
Space enthalpy	28.01
Exchanger Effectiveness	0.5
Enthalpy leaving baseline coil	22.61
Enthalpy leaving desiccant coil	27.15



Savings Estimate for Tampa

Tampa Weather (5 gr Humidity BINs)				Exhaust Recovery System (Baseline)			Desiccant	Desiccant Saving (or cost)		
HR (gr/lb)	MCDB (°F)	h (Btu/lb)	Hours	h (Entering Coil)	Coil Work (Δh)	Ton-Hours	Coil Work (Δh)	Tons	Ton-Hours	%
147.5	85.0	43.6	2	35.81	13.20	34.6	16.45	(4.27)	(8.5)	-19.8%
142.5	84.1	42.6	13	35.31	12.70	216.6	15.45	(3.62)	(47.0)	-17.8%
137.5	84.6	41.9	85	34.96	12.35	1377.2	14.75	(3.16)	(268.3)	-16.3%
132.5	84.5	41.1	261	34.56	11.95	4091.9	13.95	(2.63)	(686.8)	-14.4%
127.5	82.9	39.9	407	33.96	11.35	6060.4	12.75	(1.84)	(750.5)	-11.0%
122.5	81.2	38.7	561	33.36	10.75	7911.7	11.55	(1.06)	(592.7)	-7.0%
117.5	79.8	37.6	730	32.81	10.20	9768.1	10.45	(0.33)	(244.3)	-2.4%
112.5	78.2	36.4	810	32.21	9.60	10200.7	9.25	0.45	366.8	3.7%
107.5	76.7	35.2	490	31.61	9.00	5784.9	8.05	1.24	607.8	11.7%
102.5	76.9	34.5	386	31.26	8.65	4379.8	7.35	1.70	656.1	17.6%
97.5	75.3	33.3	514	30.66	8.05	5427.4	6.15	2.49	1278.4	30.8%
92.5	73.9	32.2	324	30.11	7.50	3187.2	5.05	3.21	1039.7	48.4%
87.5	72.1	31.0	515	29.51	6.90	4660.6	3.85	4.00	2058.2	79.1%
82.5	70.2	29.7	505	28.86	6.25	4139.3	2.55	4.85	2449.1	144.9%
77.5	68.9	28.6	396	28.31	5.70	2960.0	1.45	5.57	2206.3	292.8%
72.5	69.1	27.9	343	27.96	5.35	2406.3	0.75	6.03	2068.6	612.7%
Total dehumidification hours			**6342**	**Baseline ton-hours**		**72606.6**	**Annual Savings**		**10132.7**	**14.0%**

Assumptions	
Supply airflow	3500
Space DB	75
Space HR	65
Space enthalpy	28.01
Exchanger Effectiveness	0.5
Enthalpy leaving baseline coil	22.61
Enthalpy leaving desiccant coil	27.15



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