Costs & Benefits of Utilizing Mechanical Dehumidification Systems For Treating Ventilation Air

Carrier ®

Introduction

During the past few years there has literally been an explosion in the HVAC industry of new technologies from companies trying to capitalize on the indoor air quality (IAQ) dilemma of the 1990's. IAQ is probably **the** issue that has received more industry press the past decade than any other, especially with the recently revised ASHRAE Standard 62-99. If you have attended any of the recent ASHRAE Winter or Summer meetings and walked through the Product Show you are literally overwhelmed with every kind of product imaginable to deal with IAQ. From new elaborate filter media, new electronic measuring instrumentation to rotating heat wheels, heat pipes and other gadgets, all claiming to solve all of your IAQ problems. Many of these companies are new start-ups or spin-offs of other companies and many have new unproven technologies and are attempting to stake their territory in the competitive IAQ market.

This paper will focus on tried and true methods of dehumidification that are proven and have been used effectively for over 50 years! We will examine the costs and benefits of using a mechanical (vapor-compression) system and contrast this to the application of other alternative dehumidification strategies.

Marketing Hype

All ancillary dehumidification systems claim to offer similar benefits: Use our product and you can save energy, use smaller central cooling units and improve the comfort in your building! In most cases these claims are true, however you must look beyond generalized claims and look at specific applications to make intelligent choices as to which type of dehumidification system to use.

Market Drivers

A large portion of the commercial HVAC market utilizes unitary packaged rooftop equipment for cooling and heating. Rooftop units under 15 tons make-up the largest portion of this market. Packaged rooftop units generally cannot handle much more than about 30% ventilation air due to their inherent design. Most rooftop units use 3 or 4-row deep cooling coils and are designed with a sensible heat factor of approximately 75%. In very hot or humid environments, with relatively high quantities of ventilation air, these units cannot properly dehumidify the outside air resulting in high indoor relative humidity levels. ASHRAE recommends a maximum indoor relative humidity (RH) of 60% to prevent the formation and growth of microorganisms.

Systems Solutions

Desiccant Wheel

One such technology that has enjoyed a huge success is the enthalpy wheel, also referred to as a desiccant wheel or heat wheel. The desiccant wheel is a very effective technology for many applications. It works primarily by a chemical process whereby a material (desiccant) with an affinity for moisture is impregnated onto a rotating wheel that rotates between the incoming fresh air stream and the outgoing exhaust air stream. This desiccant adsorbs the moisture and sensible heat from the outdoor air and gives off a portion of its heat and moisture to the exhaust air. These wheels have thermal efficiencies of as high as 80-85% under certain conditions.

Desiccant systems do have drawbacks however as the desiccant material must be regenerated (dried), which in more recent designs is accomplished by using building exhaust air to regernerate the desiccant. For effective operation, the desiccant wheel depends on a temperature difference (ΔT) between the two airstreams. This means that during very hot or cold days the desiccant wheel works very well as it has a significant ΔT available to exchange heat. However, on relatively cool, humid days for instance the temperature of the outdoor air may be nearly identical to or slightly lower than the indoor temperature. During these times the desiccant wheel does not function very effectively and may in fact add heat to the ventilation air creating an additional load that must be handled by the rooftop unit. In addition, since the wheel rotates between the fresh air and exhaust air streams there is a possibility of cross-contamination due to seal leakage.

Desiccant wheels add complexity by introducing additional components into the system that must be maintained such as drive motors, belts, bearings, etc. Also, the life expectancy of desiccant wheels is not necessarily clear. New molecular seive materials claim to have long lives, however since they have only been used for a few years they are not yet proven. The final disadvantage of a desiccant wheel is the maintenance aspects. Being a specialized product, there are not a great number of service contractors that are knowledgeable and qualified to service desiccant wheels. Especially in rural, outlying areas, finding parts and a qualified service company to service a desiccant wheel system may be a challenge. One of the biggest problems encountered in the field with desiccant wheels is dirty filters and/or dirty desiccant wheels due to lack of proper maintenance. Since many contractors and building maintenance personnel aren’t qualified to service them, they tend to be overlooked and neglected during maintenance operations.

Given their limitations, desiccant wheels, when properly applied and maintained, are a viable solution to many dehumidification applications, especially in industrial and large commercial air handling systems with large amounts of ventilation air. If used they should be considered for single, large make-up air systems rather than using a large number of small desiccant wheels, each individually installed within individual packaged rooftop units for instance. The thermodynamic properties should be analyzed as well as additional energy costs from fans, pumps, drive motors and regeneration heat sources prior to applying a desiccant wheel.

MoistureMiser

To meet these design challenges, a few years ago Carrier Corporation introduced a new packaged rooftop accessory called the *MoistureMiser*. The *MoistureMiser* is a factory-installed dehumidification system that provides greater dehumidification by adding a sub-cooling coil, located on the leaving-air side of the evaporator coil, along with controls which lower the refrigerant temperature entering the evaporator. This increases the latent capacity of the system by as much as 40%.

The sub-cooling coil downstream of the evaporator re-heats the cold supply air to prevent overcooling of the space and avoid complaints of cold blow from the building occupants.

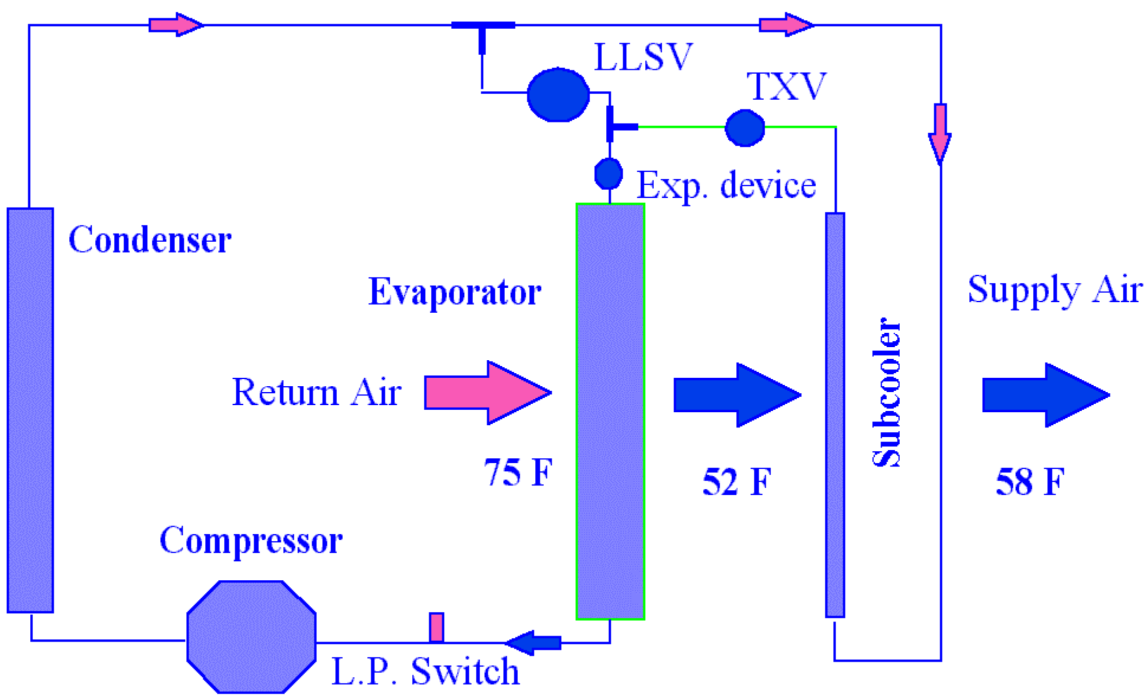

Figure 1 – *MoistureMiser* Diagram

Energy$Recycler

Carrier Corporation has recently introduced a new RTU called the COBRA *Energy$Recycler* which is a factory installed, one piece design that installs on a standard roof curb and features single-point wiring. The Energy$Recycler is also available as a rerofit kit for field installation on existing rooftop installations since 1988; it attaches directly to the rooftop unit. It preconditions the outside air entering the unit allowing the introduction of large quantities of outdoor air in hot climates where typical rooftop units can't handle the extreme conditions.

This device is a self-contained mechanical refrigeration system (similar to a room air-conditioner) that bolts right on to the outdoor air intake of the rooftop unit to precondition the outside air. In summer it dehumidifies the incoming air and rejects the condensing heat out with the exhaust air. In winter it operates in the reverse cycle as a heat pump to extract heat from the exhaust air while it pre-heats the ventilation air. Rather than using hot outside air to cool the condenser coil, it uses air being exhausted from the building allowing the *Energy$Recycler* to operate at lower condensing temperatures.

The *Energy$Recycler* effectively allows you to separate the ventilation air load from the space thermal loads. By pre-treating the ventilation air separately the main evaporator coil in the unit operates much more effectively and efficiently.

This system is more effective than desiccant or enthalpy wheel systems, especially during cooler mild weather when the temperature difference across an enthalpy wheel does not exist. The *Energy$Recycler* does not rely on the temperature difference between the outdoor air and the building exhaust air for regeneration because it creates its own ΔT through the vapor-compression cycle. This makes the *Energy$Recycler* ideal for hot and humid as well as hot and dry climate applications.

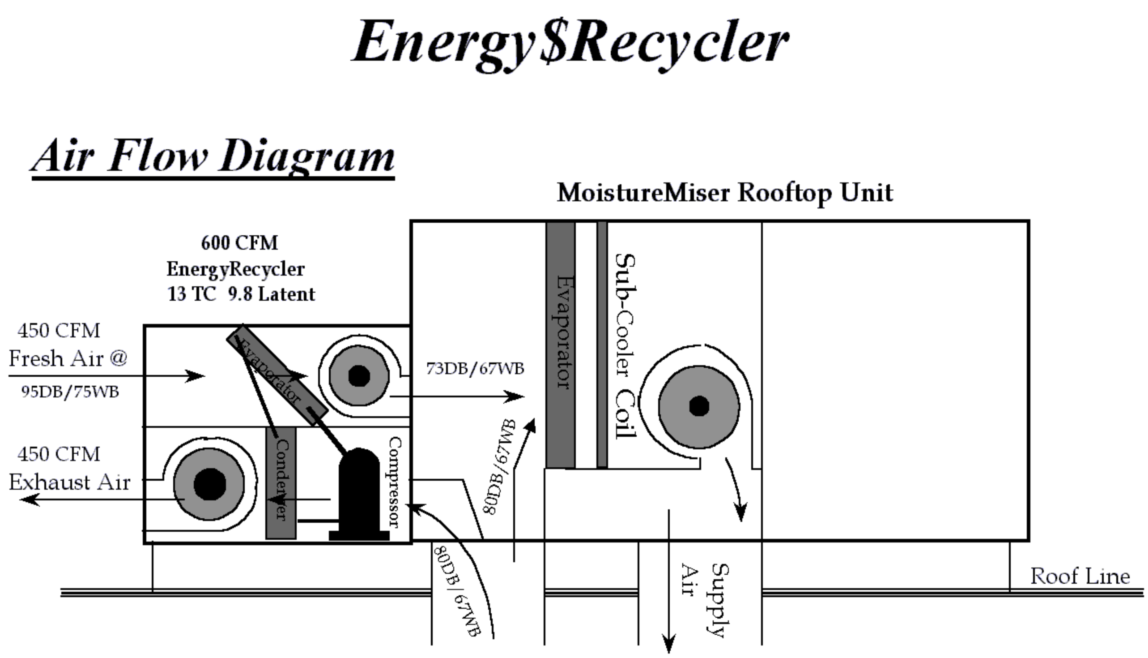

Figure 2

The *Energy$Recycler* can be used with or without a *MoistureMiser* rooftop unit depending on the amount of required latent capacity.

Dehumidification System Comparison

A systems analysis was performed for a typical restaurant in three different cities: Miami, Atlanta & Chicago. These cities represent varied weather conditions. Eight different systems were compared, each with a different dehumidification strategy as follows:

1. Baseline - Standard Rooftop Units
2. Standard Rooftop Units w/ ERV- Energy Recovery Ventilator (Desiccant Wheel)
3. Standard Rooftop Units w/*Energy$Recycler*
4. Carrier *MoistureMiser* Rooftop Units
5. Carrier *MoistureMiser* Rooftop Units w/ ERV
6. Carrier *MoistureMiser* Rooftop Units w/*Energy$Recycler*
7. Standard Rooftop Units w/ ERV & Reheat For Regeneration of Desiccant Wheel
8. Carrier *MoistureMiser* Rooftop Units w/ ERV & Reheat For Regeneration of Desiccant Wheel

The data is summarized in Table 1.

RESTAURANT STUDY											10/27/98
Sys.No.	V CFM	RT1 tons	RT2 tons	RT Op Hrs	RT Cycles	Avg DB	Avg RH	Hrs>60%	Clg kWh	Htg kWh	Tot kWh
MIAMI											
Std RT, OA	3170	12.5	15.5	2590	10646	75.1	66.2	5224	99571	1698	101269
Std RT, ERV	3170	10.0	12.5	3053	10676	75.3	63.0	4913	108981	468	109449
Std RT, ER	3170	8.5	10.0	1971	6357	74.9	59.8	3775	121584	1037	122621
MM RT, OA	3170	12.5	15.5	2798	9681	75.2	62.2	4088	106178	1697	107875
MM RT, ERV	3170	10.0	12.5	3215	9880	75.3	58.9	2883	113262	462	113724
MM RT, ER	3170	8.5	10.0	2205	5670	74.9	57.6	2433	125969	1039	127008
Std RT w/ Reheat, ERV	3170	12.5	15.5	3354	9239	75.3	60.0	3728	126331	457	126788
MM RTw/ Reheat, ERV	3170	10.0	12.5	3350	9433	75.3	58.1	2444	116260	464	116724
ATLANTA											
Std RT, OA	3170	12.5	15.5	1023	5067	73.4	55.1	2732	49032	43363	92395
Std RT, ERV	3170	10.0	12.5	1363	5897	73.9	51.5	2456	67510	19769	87279
Std RT, ER	3170	8.5	10.0	689	2703	73.0	49.6	1600	65162	33796	98958
MM RT, OA	3170	12.5	15.5	1096	4734	73.4	53.4	2174	61372	43356	104728
MM RT, ERV	3170	10.0	12.5	1418	5602	73.9	49.7	1646	69066	19761	88827
MM RT, ER	3170	8.5	10.0	773	2511	73.0	48.8	1180	66462	33796	100258
Std RT w/ Reheat, ERV	3170	12.5	15.5	1551	5180	73.9	49.7	1631	77367	19573	96940
MM RTw/ Reheat, ERV	3170	10.0	12.5	1569	5212	73.9	48.6	1181	72249	19733	91982
CHICAGO											
Std RT, OA	3170	12.5	15.5	648	3500	72.8	46.9	1280	35702	105298	141000
Std RT, ERV	3170	10.0	12.5	889	4192	73.1	43.3	1080	54110	52072	106182
Std RT, ER	3170	8.5	10.0	486	2023	72.4	41.2	590	43900	88533	132433
MM RT, OA	3170	12.5	15.5	695	3304	72.8	45.7	920	37186	105310	142496
MM RT, ERV	3170	10.0	12.5	925	4014	73.1	42.2	624	55062	52069	107131
MM RT, ER	3170	8.5	10.0	546	1893	72.4	40.7	388	44618	88530	133148
Std RT w/ Reheat, ERV	3170	12.5	15.5	1037	3754	73.1	42.3	593	57249	52085	109334
MM RTw/ Reheat, ERV	3170	10.0	12.5	1003	3807	73.1	41.6	382	56710	52070	108780

Table 1

For simplification let's focus our discussion on the Miami data only. The baseline system (#1) utilized standard rooftop units for a total installed capacity of 28 tons (see Table 1). Notice by adding the ERV – Energy Recovery Ventilator (#2) the required installed capacity of the rooftop units was reduced from 28 to 22.5 tons. Notice the rooftop unit operating hours increased from 2,590 to 3,053 hrs. This also reduced the average room relative humidity (RH) from 66.2 to 63% but required more total energy (last column on right). Note the number of hours per year where the room RH was greater than 60% (4,913 hrs.). To reiterate, ASHRAE recommends that indoor RH be kept below 60% at all times to prevent the growth of mold spores and other microorganisms.

Using the *Energy$Recycler* (#3), the installed equipment capacity was reduced even further than when using the ERV, 18.5 tons vs. 22.5 tons. By de-coupling the ventilation air load from the space thermal loads notice the drastic reduction in operating hours for the rooftop units with the *Energy$Recycler:* 1,971 hrs. Also, notice the room temperature was reduced to 74.9 ^{o}F from 75.3 ^{o}F and the room RH was reduced from 63 to 59.8% as compared to the ERV. The hours of operation above 60% RH was also reduced to 3,775 hrs. However, this improvement in comfort did have a negative impact on the energy consumption, which increased to 122,621 kWh.

The next system (#4) added the *MoistureMiser* dehumidification option to the standard rooftop units. As compared to the standard rooftop units (#1), notice the operating hours increased due to the fact that the *MoistureMiser* units run longer in the cooling mode to dehumidify the space as is confirmed by the lower RH at 62.2 %. The room temperature held constant while the number of hours of RH above 60% dropped from 5,224 to 4,088 hrs. The energy consumption also increased slightly to 107,875 kWh.

System #5 added an ERV to the *MoistureMiser* units (#4). This allowed us to downsize the installed rooftop unit capacity as before and it had a dramatic improvement in the space RH, which dropped from 62.2 to 58.9%. The runtime increased somewhat as well as the annual energy consumption.

System #6 added the *Energy$Recycler* to the *MoistureMiser* units. Again this allowed us to downsize the installed tonnage of the rooftop units to 18.5 tons. This change resulted in a reduction in the average RH to 57.6%, the lowest of all systems analyzed, and with only 2,433 hrs. above 60% RH. The rooftop unit's operating hours were also drastically reduced from 3,215 to 2,205 hrs. as compared to the ERV units. Fewer runtime hours results in increased equipment life and reduced maintenance costs.

System #7 was the same as system #2 except a reheat coil was added to reheat the air and prevent overcooling of the space. This allows a direct apples to apples comparison of the *Energy$Recycler* to a rooftop unit with an ERV. This was an improvement over System #2 (with only the ERV unit), however not as effective as System #6.

The last system (#8) utilized the *MoistureMiser* device with both an ERV and an electric reheat coil. This was the second best alternative however the installed capacity of the rooftop units was 22.5 tons verses 18.5 tons for System #6.

Summary & Conclusions

System #6, utilizing the *MoistureMiser* device with the *Energy$Recycler,* turned out to be the best alternative for all three cities analyzed. The installed capacity of the rooftop units was minimized along with the runtime hours as well as the hours above 60% RH. The resulting room temperature was also the lowest of all systems indicating that the thermostat setpoint could be raised slightly with no degradation in comfort levels resulting in additional energy savings.

The reader should realize that for this particular example, System #6 turned out to be the best alternative from both a comfort standpoint as well as minimizing the required installed rooftop unit capacity, however this is not necessarily the case under all weather conditions and operating parameters. You should analyze your particular application in your particular weather conditions prior to making a final design decision.

To assist you in analyzing these types of applications, Carrier Corporation has developed a software program called "CYCLE4.EXE", that complements Carrier's RTU E-CAT E20-II selection software. The software is included on the *Indoor Air Quality* CD-ROM (Carrier Literature Order Number #888-292). This as well as E-CAT is available for download on the Internet at Carrier's Home Page free of charge!

Contact your local Carrier representative to find out more about the new COBRA or 62AQ Energy$Recycler or visit Carrier's Commercial Systems website: www.commercial.carrier.com.

References

1. ASHRAE Standard 62-1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating Refrigerating and Air-Conditioning Engineers; Atlanta, Georgia; 1990; p.22.

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