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IMPROVING HVAC SUSTAINABILITY AND PERFORMANCE

Avoiding Wet & Moldy AHUs In Critical-Care Facilities

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Anyone who has experienced the wet inside an HVAC air-handling unit (AHU) serving critical-care environments knows this situation can create a breeding ground for mold and microbial growth, an unacceptable condition particularly when serving hospital patient care areas or other such sensitive settings. Engineering controls outlined in this article are intended to positively impact both the performance and hygiene of air-handling systems by improving a building's indoor air quality, helping protect exposed occupants from airborne and surface source contaminants and improving building sustainability.

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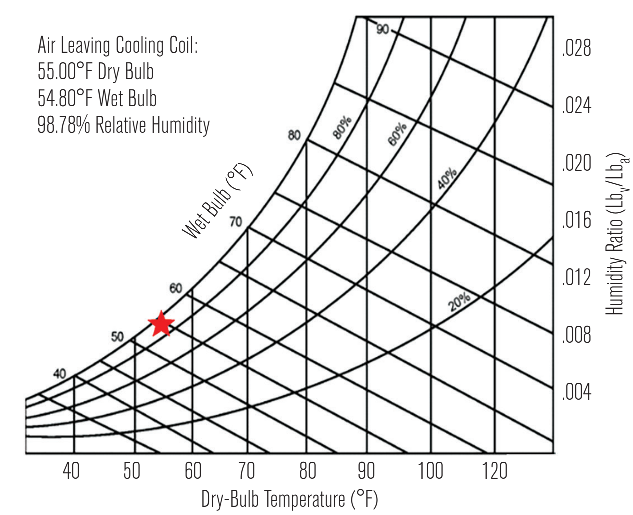
PHOTO 1 Microbial contaminated chilled water cooling coil in hospital AHU.

FIGURE 1 Leaving air conditions from cooling coil near saturation.



Mold, fungi and bacteria growing on HVAC system components can be aerosolized and distributed by ductwork to various spaces within the building, resulting in considerable concern regarding occupant well-being.[1] One issue is wet and moldy air filters, which create unsustainable operating conditions for air handling in any HVAC application. In addition to health consequences, this moisture may reduce filter life or efficiency and add additional airside pressure drop, which increases fan energy consumption and operational costs.[2]

Filters become wet for various reasons, most of which can be eliminated with proper AHU design, selection and control. Ensuring cooling coils are kept clean and air velocities through coils are kept low enough to prevent moisture carryover (blow-off) into the airstream is critical. If humidification devices have been inadvertently installed upstream of filters, their humidistat, sensors and valves must be properly installed and functioning correctly. But even with the most judicious AHU design, final filters may still become wet for what appears to be no good reason. Besides physical wetting by condensate carryover, another relatively simple explanation exists as to how this can happen.

HVAC System Dynamics

Cold air leaving a refrigerant-based direct-expansion (DX) or chilled water cooling coil will typically approach saturation (the air is near 100% relative humidity)[3] (*Figure 1*). When this airstream enters a final filter (*Figure 2*), or any component that increases its velocity, the pressure and temperature of the air will drop as the air accelerates. Even a slight increase in air velocity accompanied by a small drop in temperature may be enough to allow the airstream to cool to a point where moisture is condensed. In cooling systems that operate for many hours a day, considerable amounts of moisture may collect on filters or other internal surfaces within the AHU. If there is not sufficient downtime that allows for this moisture to evaporate, filters will remain wet and microbial growth can proliferate.[4]

This wetting situation may be more evident with blow-through fan configurations and when filters are positioned immediately downstream of cooling coils in what is considered the final-filter position.

When designing a critical-care AHU that includes final filters, one may consider using a draw-through (cooling coil located before the fan) versus

FIGURE 2 Typical HVAC final filter location (in draw-through AHU).

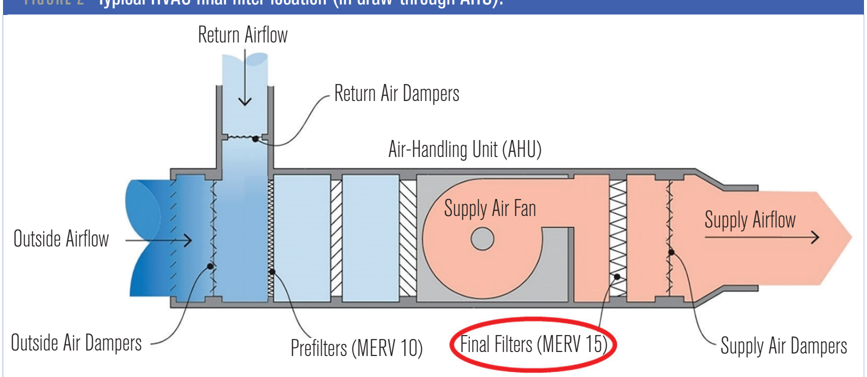
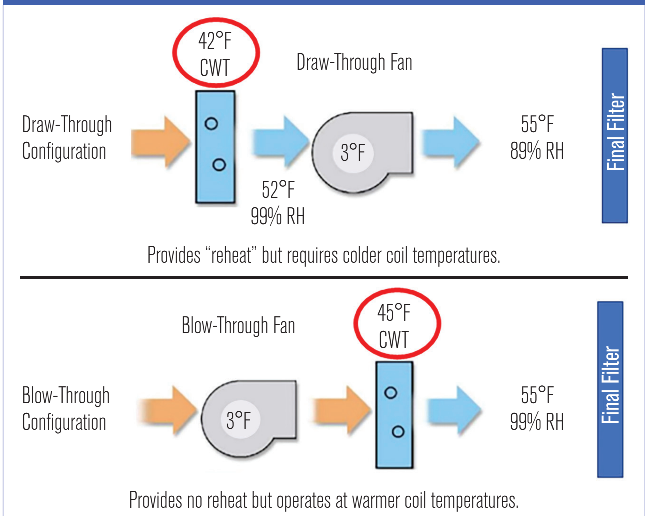


FIGURE 3 Draw-through versus blow-through fan configuration considerations.



blow-through (cooling coil located after fan) configuration. This allows the residual motor heat from the draw-through fan to be used as a source to heat the airstream leaving the cooling coil, moving its final condition slightly off the saturation point (reducing relative humidity) usually enough to avoid any moisture condensation downstream.[5] The problem with this design is that it may be less energy-efficient than an alternative design using a blow-through fan.

As shown in *Figure 3*, with a 10°F (-12°C) chilled water supply to coil leaving air approach, and to provide supply air conditions of 55°F (13°C), the cooling coil used in a draw-through fan configuration receives chilled water at a supply temperature of 42°F (6°C), resulting in a coil leaving air temperature of 52°F (11°C) and near saturation. This air is then gaining approximately 3°F (1.2°C) of fan motor heat, raising its final discharge temperature to the required 55°F (13°C) necessary to satisfy the space cooling load.[5] The air is cooled 3°F (1.2°C) colder than the required supply air temperature to account for fan motor heat, and in doing so this added heat does not become a space cooling load component.

All things being equal, the blow-through AHU configuration can provide the same 55°F (13°C) leaving air temperature from a coil supplied with 45°F (8°C) chilled water, but the motor heat is removed by the cooling coil and not added directly to the discharge air leaving the coil. This can allow the chiller serving the blow-through AHU to operate with 3°F (1.2°C) lower "lift," saving considerable compressor motor energy and operational cost.[6] Instead of subcooling the air to account for heat added after the fan, this same fan heat can be more effectively removed at the cooling coil before it becomes a space load component.

However, while the draw-through fan has added reheat to the nearly saturated air leaving the cooling coil, potentially eliminating the wetting issues discussed above, the blow-through AHU's discharge air is very near saturation, which may result in final filter wetting as noted. If an AHU with a blow-through cooling coil is engineered properly to eliminate the risk of condensate blow-off and/or final filter wetting, it can allow warmer chilled water temperatures due to the removal of fan heat at the coil and may result in a more energy-efficient and sustainable HVAC system design.

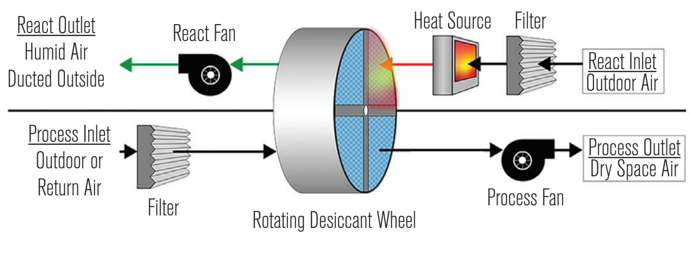
Solving Problems and Improving Performance

Moving away from wet final filters and toward a more sustainable HVAC system can be collectively accomplished. One way to achieve this task is to decouple the AHU's sensible cooling requirements from its latent load, allowing each component to be addressed individually and more effectively. If the cooling coil is required to do only sensible cooling (no condensation) because it receives air that has been properly dehumidified for the application, the more energy efficient blow-through configuration can be used without incident.

This can be accomplished various ways in theory, but one of the most practical and cost-effective approaches may be to supplement traditional HVAC system design with desiccant dehumidification. A desiccant dehumidifier is capable of very deeply drying an airstream and can provide latent cooling capabilities (moisture removal) far beyond what refrigerant-based systems can achieve.[7]

A desiccant dehumidifier removes moisture from the air by means of a desiccant—a substance that adsorbs water in its vapor state. This desiccant (silica gel, molecular sieve or activated alumina) is impregnated into a fluted wheel (called the rotor) (*Figure 4*). The rotor is divided into two sectioned airstreams, process and reactivation, and rotates very slowly (3 RPH to 30 RPH). When the process air

FIGURE 4 Desiccant dehumidification cycle.



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(outdoor air or return air from a conditioned space) is passed through the rotor, the moisture in the airstream is adsorbed by the rotor, leaving the dried air to be sent to the designated space via a supply air fan. The water from the processed air adsorbed by the rotor now must be removed to continue the indefinite process. The reactivation air provides this task. The airstream is normally outdoor air heated to allow the bound moisture in the desiccant to be released (desorbed) from the wheel. This airstream is extremely humid and is ducted outside.

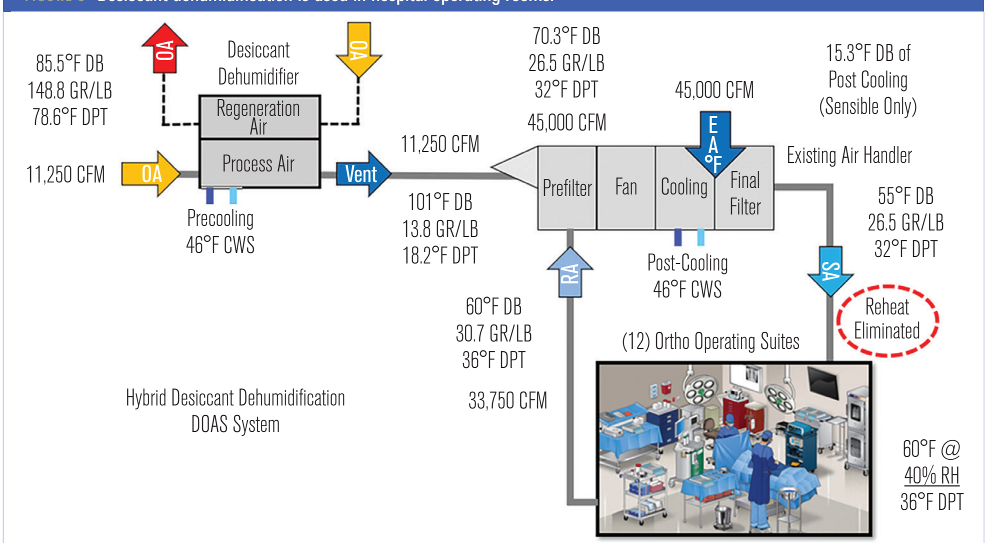
Desiccant dehumidification can provide extremely dry air, with resulting dew-point temperatures of –80°F (–62°C) or lower being achievable.[8] This provides the unique opportunity for a desiccant system to deeply dry a small airstream that when mixed with a larger, more humid quantity of air can still provide the total dehumidification capacity required to achieve very low dew-point temperatures and relative humidity in a space.

Figure 5 is an example in which this concept was applied to retrofit an ailing HVAC system in a Colorado hospital to help cool and dehumidify orthopedic operating rooms. Facility engineering struggled daily to maintain compliant space conditions, and on design dehumidification or "monsoon" weather days found it impossible to satisfy their surgeon's demands for operating room comfort and productivity.

A decision was made to treat only the smaller outdoor (ventilation) airstream with desiccant-based technology to minimize the equipment's size and first cost. 11,250 cfm (5309 L/s) of ventilation air is deeply dried and delivered to a standard cooling-based air handler that blends it with 33,750 cfm (15 928 L/s) of return. This requires the AHU to perform only the sensible cooling and heating functions required to satisfy the temperature demands of the operating room, as the latent load has already been addressed by the desiccant unit. The absence of the latent load in the airstream also allows the operating room space temperatures to be adjusted rapidly.[9]

Traditional cooling systems are limited to supply air dew-point temperatures of approximately 40°F (4°C) and higher.[7] This desiccant-assisted design provided 32°F (0°C) dew-point temperature air to the operating room, allowing space conditions to be consistently maintained at 60°F (16°C) and 40% relative humidity (RH) in even the most humid of outdoor ambient conditions. As a bonus efficiency initiative, the central plant chilled water temperature was increased from 42°F (6°C) to 46°F (8°C), improving chiller efficiency by approximately 6%. The air entering the AHU's final filter has been desiccated to a condition that eliminates any chance of the downstream condensation and wetting issues contributed by coil moisture blow-off or increased air velocity.

FIGURE 5 Desiccant dehumidification is used in hospital operating rooms.



Of great significance in this example is that the need for costly "reheat" has been eliminated, which in conventional operating room design may range anywhere from 15°F to 30°F (–10°C to 4.0°C).

In a time when every dollar must be accounted for, this design allows health-care facilities to maintain the surgical procedures that yield the most profit, without the fear of losing surgeons to competing facilities where operating conditions are more comfortable and productive.[9]

Desiccant dehumidifiers may use refrigerant-based pre- and post-cooling devices to enhance efficiency and effectiveness. But without being coupled with desiccant dehumidification, traditional cooling technologies (alone) may be incapable of meeting the more stringent environmental space requirements of this example.

Improving HVAC System Outcome

Transmission by aerosols is considered the main route for the spread of COVID-19 (and other) infections indoors. Therefore, limiting air transfer between supply and exhaust air in HVAC ventilation systems is critical.[10] Unlike energy recovery or passive desiccant dehumidification systems that use rotary wheel heat exchangers that work on the premise of creating high exhaust air transfer ratios, active desiccant dehumidifiers (as described above) do not exchange energy from a building's return or exhaust airstreams, avoiding this potential pitfall.

Any HVAC system surface that is not regularly cleaned or possibly disinfected can harbor pathogenic microorganisms and biofilms.[11] Areas of a critical-care AHU system that could potentially harbor such contamination include the fan, coil, drain pan, filters and ductwork, particularly if there has been a buildup of dust or residue on these inside surfaces, which (when chilled and wetted) can proliferate microbial growth. In this example, using desiccant dehumidification to remove all associated ventilation and building-related latent loads will keep downstream AHU componentry dry, significantly reducing the chance of any moisture occurrence. Benefits to consider when applying desiccant dehumidification as a method to enhance environmental control include:

1. AHU cooling coils can be selected to handle sensible-only cooling loads. This may lower system first costs by reducing the number of coil-rows and fins while lowering fan horsepower requirements to conserve energy, reduce carbon emissions and save operational expense.

2. Downstream AHU and ductwork (internal) surfaces and componentry can remain dry, lessening concerns with microbial growth and its aerosolization and distribution into occupied environments.[4] While this eliminates wet final filters and extends their useful life, it may also reduce or eliminate the need for manually cleaning bio growth from cooling coils and drain pans or

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eliminate the necessity for installing and maintaining energy-intensive UV-C lights for this same purpose. Keeping wet cooling coils clean is important, but it can be a recurring expense, which negatively impacts overall cost of ownership.

3. External AHU and ductwork surfaces may be maintained at higher temperatures because the air being conveyed through them doesn't need to be deeply cooled to also dehumidify it. Conveying cold, saturated air to reheat boxes will challenge insulation to prevent condensation on metal exteriors. Desiccant dehumidification can lessen the risk of surface condensation and possibly reduce the cost for the construction, materials and insulation of these components.

4. Keeping cooling coil surfaces free of biofilm contamination maintains design cooling coil performance, pressure drop and heat transfer efficiency. Various guidance suggests this has the potential for a savings in energy of between 10% and 25%.[12]

5. Lowering indoor relative humidity can easily be accomplished with desiccants. Reducing space relative humidity may allow for maintaining a higher indoor dry-bulb temperature, which can foster superior levels of occupant comfort and satisfaction.[13] This will also lower the temperature difference between the indoors and outdoors, reducing space heat gain to garner energy and operational cost savings. Maintaining lower indoor relative humidity also helps reduce the probability of mold growth both interstitial to building materials and on indoor surfaces and helps mitigate its concern from occupant exposure.

6. If low-cost or no-cost waste heat (cogeneration, heat recovery, etc.) can be used for the desiccant regeneration process, operating costs for dehumidification can be reduced to a mere fraction of any competing technology. Recovery strategies incorporated to recoup reactivation air heat can provide substantial energy and utility cost savings.

7. Central cooling plants may be allowed to operate at higher refrigerant evaporator temperatures, reducing compressor lift and increasing chiller efficiency. This can considerably reduce HVAC energy use and lower utility bill costs.

8. Desiccant dehumidification can decouple latent load requirements from refrigerant-based central plants, freeing up additional cooling capacity that can be used elsewhere or for future facility expansion. This also unloads cooling towers, reducing water and chemical treatment, resulting in capital and operational cost savings.

9. Applying desiccant dehumidification properly can reduce or eliminate the need for costly reheat energy. When air is "over-cooled" to properly dry it, it is often necessary to add heat back into the airstream to warm it to a temperature suitable for achieving occupant comfort. Reheat can account for up to 65% of a large hospital's natural gas energy consumption.

Conclusion

The engineering controls outlined in this article are intended to positively impact both the performance and hygiene of air-handling systems by improving a building's indoor air quality, helping protect exposed occupants from airborne and surface source contaminants and improving building sustainability. While desiccant dehumidification may be more familiar to those engineers working in settings that require precise control of relative humidity or dew-point temperature, such as in aerospace, pharmaceutical, food processing, cleanroom, laboratory, semiconductor manufacturing and other industrial applications, it is certainly applicable for less demanding yet still critical environments, including hospitals and others. Traditional refrigerant-based cooling technologies are usually incapable of achieving the dew-point temperatures required to achieve the psychrometric outcome and operational benefits detailed in this article.

Desiccant dehumidification, when properly applied, installed and operated, can help any indoor environment (particularly those deemed critical) achieve a more productive, energy efficient and sustainable footprint. It is worth consideration in today's world where unique solutions are required to solve a multitude of complex issues within buildings everywhere.

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