DESIGNING FOR HUMIDITY CONTROL IN THE OPERATING ROOMS

Desiccant Dehumidification Case Study for HEALTHSOUTH Medical Center

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PRESENTATION ABSTRACT:

Battling for control of the humidity within the operating rooms, this HEALTHSOUTH retrofitted the existing chilled water-based Air Handling Unit with a desiccant-based Air Handler in their flagship medical center. This case study shows results, design parameters and practical options for hospitals.

THE PROBLEM:

Long gone are the days when satisfactory space conditions for the operating rooms were around 68^0F to 73^0F and 50% relative humidity. Today, due to the heavy, multiple layered gowning and the long procedures, most surgeons are requiring that their surgical suites be maintained at 60^0F to 65^0F or lower during the procedures. In addition to the concern for the surgeon's comfort, it is often necessary to maintain lower conditions in the operating rooms due to therapeutic reasons or to keep the adhesive cements used in orthopedics from setting too quickly. Even at these lower temperatures, the relative humidity in the space is still expected to be maintained near 50%. With conventional HVAC systems (i.e., chilled water or DX-based) this is very difficult to achieve, as the relative humidity will typically be found to be above 60%. These conditions result in a less than desirable operating room environment.

This was the case with the HEALTHSOUTH Medical Center in Birmingham, AL. This hospital, like so many others, had HVAC mechanical systems installed to meet the minimum space conditions as set forth in the AIA guidelines for surgical suites of hospitals (i.e., 68F to 75F drybulb temperature with a coincident relative humidity of 30% to 60%). As the surgical staff desired cooler temperatures than the designed setpoint of 68F drybulb and 50% RH, upon arrival into the surgical suite they would lower the thermostat setting to anywhere from 55F to 60F degrees. When the originally installed HVAC system was designed with chilled water cooling coils capable of supplying only about 52F *dewpoint* air, the resulting relative humidity levels at these much cooler temperatures ranged from 65% to 75% RH most of the time (couldn't reach lower relative humidity levels with the conventional, existing equipment). These conditions left the operating rooms cold and clammy, just as uncomfortable as before. However, now the added concern of it "raining" in the operating room was often present. This phenomenon occurs whenever the dewpoint of the surrounding air is higher than the surface temperature of the ceiling or other objects within the space. Obviously, having the potential for this condensate dripping from overhead onto a patient was of even greater concern to the staff than the surgical staff's comfort.

Below is a schematic of the existing air handler that served the surgical suite (Figure 1). The lower air handler conditioned and delivered approximately 38,000 cfm of air using the 42F chilled water coils as the method of cooling and removing moisture from the mixture of outside air (12,000 cfm) and the return air (something slightly less than 26,000 cfm). The coils, with only 42F entering chilled water had a supply air dewpoint of approximately 52F. As can be determined from the psychrometric chart, this dewpoint at a coincident drybulb temperature of 60F will result in an uncomfortable 75% RH in the space. Since the overwhelming majority of the moisture coming into the surgical suite is being introduced through the ventilation airstream, it was determined that the moisture should be removed at this point, rather than relying on the downstream air handler to remove it. Understanding that the dewpoint of the air at the targeted condition of 60F drybulb and 45% RH was 38.6F dewpoint (or 34.4 grains of moisture / pound of dry air), it was obvious that a desiccant-based air handler would be required. This system would be designed to pre-condition the required ventilation air to well below the 34.4 gr/# condition in order to also compensate for the internal latent gain (i.e., moisture addition) expected in the operating suites.

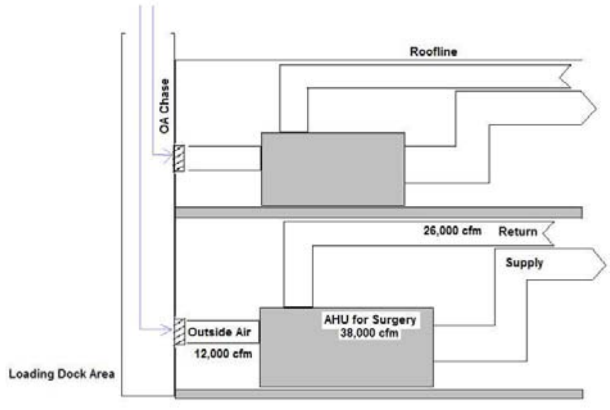

Figure 1: Elevation showing the air handler currently serving the hospital's surgical suite.

THE SOLUTION:

As shown in the following schematic (Figure 2), the desiccant dehumidification unit was selected to pre-condition the 12,000 cfm of ventilation air prior to it mixing with the return air from the operating suite. The intent of the design, as stated above, was to have the capability of drying the air sufficiently in order to compensate for the latent gain expected within the space. In this case, the desiccant pre-conditioner was designed to deliver air into the existing air handler at a specific humidity condition of as low as 16.4 grains of moisture / pound of dry air (equivalent of approximately 20F dewpoint) (See Figure 3 below). Not knowing the exact latent gain that must be compensated for from the areas surrounding the surgical suite, the system was designed with sufficient drying capacity.

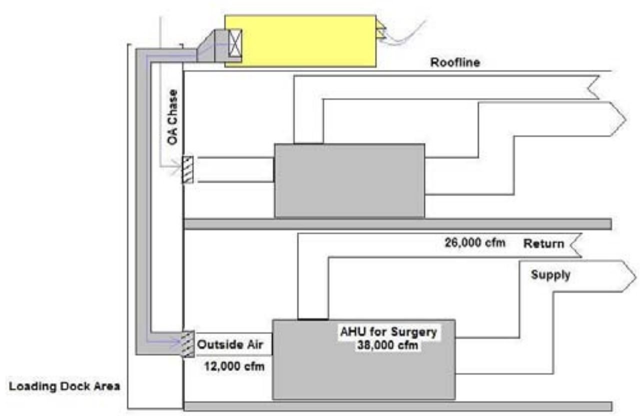

Figure 2: Elevation showing how the desiccant pre-conditioner was installed to treat the ventilation air for the surgical suite.

SUMMER OPERATING CONDITIONS

STATE POINTS	A	B	C	D	E	F	G	H		K	L	M	N
VOLUME SCFM	12,000	12,000	12,000	12,000	0	12,000	12,000	12,000		4,000	4,000	4,000	4,000
TEMPERATURE F	83.0	83.0	50.8	50.8	-	88.4	92.9	70.0		83.0	83.0	284.0	171.2
MOISTURE Gr/Lb	135.0	135.0	54.2	54.2	-	16.4	16.4	16.4		135.0	135.0	135.0	248.4

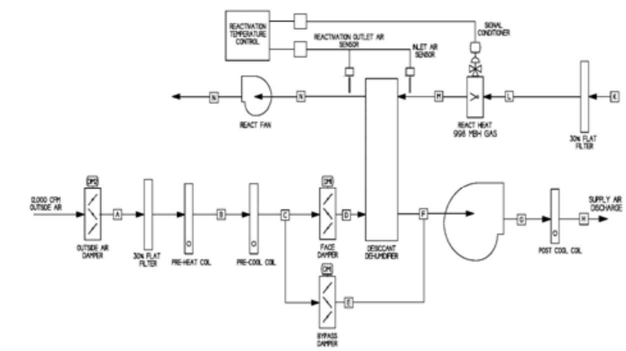

Figure 3: Flow schematic and operating conditions of the desiccant dehumidification unit.

By incorporating a desiccant-based dehumidification system into the mechanical design for the hospital's operating suite, the overall system was designed for optimal and *active* humidity control (see Figures 4 and 5 below). No longer does the surgical staff have to tolerate less than desirable space conditions. No longer is there a threat of it "raining" in the operating room during surgeries (i.e., condensate forming and dripping from the metal fixtures on the ceiling). The common problem of the fogging of microscope lens has also been eliminated by the lowering of the dewpoint of the air in the operating rooms. By incorporating the desiccant system into the mechanical design, the *absolute* humidity levels can be dropped much lower than the chilled water coils are capable of achieving. Regardless of the temperatures desired in the space, the humidity levels can be dropped low enough to avoid the excessive humidity problems of the past.

Figures 4: Desiccant dehumidification system at HEALTHSOUTH (regeneration side)

Figure 5: Desiccant unit showing side with pre-cooling and pre-heating coils

There were additional benefits that resulted from the addition of the desiccant pre-conditioning unit. For one, the cooling coils in the existing downstream air handler are kept dry. With the dewpoint of the air flowing through the existing coils being maintained lower than the coil temperature, there is no condensate on the coil's surface or in the drain pan. Specifically, the air being supplied by the desiccant unit is approximately 20F dewpoint. There is no moisture condensing on the cooling coils because the surface temperatures are much higher (i.e., between 42F and 52F degrees). This will result in tremendous savings of man-hours normally attributed to the periodic cleaning of the coils, not to mention the associated improvement in the quality of the supply air in the ductwork. This dry air should also significantly reduce the very real concern of nosocomial infections. The elimination of moisture in the ductwork is a major step in reducing the habitat for mold spores to grow. In addition to the health benefits realized by keeping the humidity levels under control, the absence of the latent load in the airstream allows the space temperatures to be adjusted very rapidly.

DESICCANT TECHNOLOGY:

A "desiccant" is any material that has a great affinity toward moisture. In the majority of the commercially available desiccant-based dehumidification systems, Silica Gel desiccant is used and is impregnated onto the substrate material of the rotor (or wheel). This desiccant rotor removes moisture in the vapor stage from the "process" airstream by adsorption. This is the airstream that is to be dehumidified, whether it is all outside air or a mixture of OA and return air. As the rotor rotates, the moisture-laden rotor then rotates through a section of the air handler known as the regeneration section. In this section, the rotor is dried with heat from either a gas fired burner, a steam coil, or even an electric resistance heater. This process operates continuously as long as there is a need for dehumidification (see Figure 6 below).

Many healthcare engineers and/or plant operations managers have a misunderstanding that a desiccant system is the same as an energy recovery (i.e., enthalpy wheel) system. While both systems include a rotor (or wheel) with a coating of desiccant material, the similarities of the two technologies stop there.

The true desiccant system is *actively* regenerated, as opposed to *passively* regenerated by the requirement of cooler, drier exhaust air. Active regeneration means that there is a heat source, usually a direct-fired natural gas burner or steam coils that is "regenerating" the desiccant material bonded on to the rotor. The actively regenerated system does *not* require exhaust air to function; however, energy can be recovered from the hospital's exhaust air if desired and practical. The actively regenerated desiccant system also includes two to three times the amount of desiccant material by weight than does an enthalpy, or energy recovery, rotor. With this increased amount of desiccant material on the rotor, the amount of moisture that can be removed is increased proportionally.

A desiccant system can be added to strictly condition the outside air requirements of the surgery suite, or it can be sized to treat the entire supply air requirements of the suite.

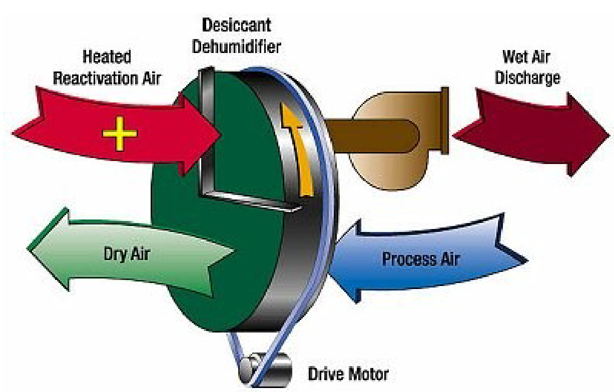

Figure 6: Actively regenerated desiccant

dehumidification rotor (i.e., wheel)

Often times, especially when lower absolute humidity levels are desired, cooling coils will be integrated into the system prior to the desiccant rotor. Because of their positioning before the rotor, they are typically called “pre-cooling” coils. Their purpose is to remove the excess moisture that is above the dewpoint of the coils, thereby leaving the desiccant rotor to remove the more difficult moisture which is that below the dewpoint of the coils. For example, in this case for the HEALTHSOUTH unit, the cooling coils dehumidify the ventilation air down to about 50F dewpoint (50.8F drybulb and 54.2 gr/#) and then the desiccant rotor dries the air further to the desired levels, all the way down to almost 20F dewpoint if desired. The desiccant dehumidification systems that have integral “pre-cooling” coils are often called “hybrid” systems because of their use of the two technologies (i.e., mechanical and desiccant). The psychrometric path the air will take when being processed through the unit designed for HEALTHSOUTH is as shown below in Figure 7.

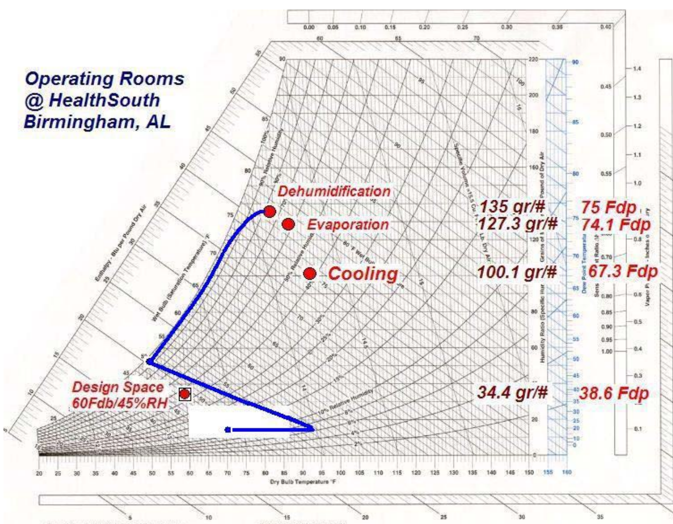

Figure 7: Process of desiccant unit at HEALTHSOUTH

THE RESULTS:

Immediately following the installation of the desiccant unit, the relative humidity in the space dropped considerably. Initially, the only controller for the desiccant unit was that of a supply air dewpoint controller sensing the air being delivered from the desiccant unit. This adjustable transmitter was initially set on 30F dewpoint until the necessary supply air dewpoint could be determined. Also, the hospital’s building automation system would eventually tie in to the system to take control of the unit as determined by the relative humidity in the operating rooms. As seen in the following graph, the relative humidity dropped in the operating suite from about 67% RH to 50% RH within 1 ½ hours and then down to approximately 42% RH within the first 3 hours. Adjustments were then made on the dewpoint controller to try to level out the humidity around 45% until the building automation system would be connected and be able to control the humidity level consistently at 45% RH (See Figure 8).

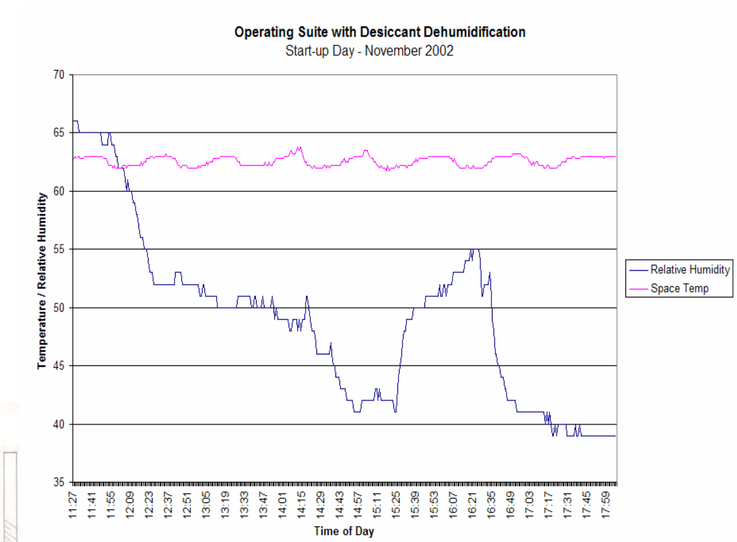

Figure 8: Temperature and Humidity Trend Immediately After Start-up

After a few months of fine tuning the controls, the humidity levels within the operating suite (12 operating rooms) can easily be kept within the desired range of 45% to 50% at the lower temperatures desired by the surgeons. After operating in a variety of space conditions over the past few months, the consensus of the surgeons is that the optimum conditions for the operating room during the surgical procedures is 62F drybulb and 45% to 50%RH (i.e., 40F to 43F dewpoint). With the desired conditions now easily achievable, the early morning “distress” calls to the facilities management department from the surgery staff have become a thing of the past.