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## Health-Care HVAC

# Temperature & Humidity Control In Surgery Rooms

By John Murphy, Member ASHRAE

Occupant comfort, infection control, and drying of mucous coating are some reasons why temperature and humidity control are important in surgery rooms.<sup>1</sup> Temperature and humidity ranges, and minimum air-change rates often are prescribed by local codes or by industry-accepted guidelines (*Table 1*).

Surgeons also have preferences when it comes to temperature and humidity conditions. Reasons for these preferences range from personal comfort while dressed in heavy surgery clothing to the perception of superior procedure success rates. Often, the result is that the surgeon expects a lower room temperature than that stated in guidelines.<sup>1-3</sup>

Don Garrison, chief of facility management at Franklin Memorial Hospital

in Farmington, Maine, said, "We always had problems being able to satisfy the surgeons, who wanted the temperature at 62°F to 65°F (17°C to 18°C), while the anesthesiologists and other staff wanted higher temperatures."<sup>4</sup>

This article discusses how the temperature and humidity requirements of surgery rooms impact the design of the HVAC system, and presents system alternatives that can meet both of these

requirements. This analysis focuses on cooling and dehumidification; heating and humidification are not addressed.

### Impact on HVAC System Design

The temperature and humidity control requirements for a surgery room, along with the high air change rate, significantly impact the design of the HVAC system. Using a rule of thumb (such as 400 cfm/ton [54 L/s per kW]) or a traditional temperature-only design approach often leads to a system that is unable to meet requirements.

The American Institute of Architects (AIA) design guidelines<sup>2</sup> recommend 15 air changes per hour (ACH) of supply air for a surgery room, and 20% of that supply must be outdoor air. As an example,

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for a 450 ft<sup>2</sup> (42 m<sup>2</sup>) surgery room with a 10 ft (3 m) ceiling height, 15 ACH equates to 1,125 cfm (531 L/s) of supply air. Assuming this is an interior space, and using typical lighting, equipment, and occupancy levels, the sensible cooling load in the space is 8,190 Btu/h (2.4 kW) and the latent cooling load is 1,600 Btu/h (0.47 kW). These loads are used to calculate the space sensible heat ratio (SHR), which helps determine how cold and dry the supply air must be to maintain both the desired temperature and the desired humidity level in the space. For this example, the space SHR is 0.84, meaning that 84% of the space cooling load results from sensible heat gain.

For design conditions, assume that the space air condition (RA) is 62°F (17°C) dry bulb and 60% RH. This equates to 50 gr/lb (7.2 g/kg), or 48°F (9°C) dew point. (Even though this temperature is colder than the AIA guideline, it is still likely that the surgeons will turn down the thermostat.)

When drawn on a psychrometric chart (*Figure 1*), the 0.84 space SHR line extends from the desired space condition (RA) to the point of intersection with the saturation curve. To offset the space sensible and latent cooling loads, and maintain the desired space condition, the condition of the supply air (SA) must lie somewhere on this SHR line.

First, let's review how a temperature-only design approach—that is, one that considers only the sensible load in the space—affects the ability of the HVAC system to meet the humidity requirements of the surgery room.

The sensible heat gain equation determines that to offset the space sensible load ( $Q_s$ ) of 8,190 Btu/h (2.4 kW) while maintaining the space temperature at 62°F (17°C), the 1,125 cfm (531 L/s) of supply air must be delivered at 55°F (13°C) DB.

$$Q_s = 1.085 \times 1,125 \text{ cfm} \times (62^\circ\text{F} - T_{sa}) = 8,190 \text{ Btu/h} \\ \therefore T_{sa} = 55^\circ\text{F}$$

Because the required air-change rate is high (15 ACH compared to 6 ACH for a typical office), the  $\Delta T$  must be smaller than

in most standard designs. In this example, the supply air is only 7°F (4°C) colder than the space, not 20°F (11°C) colder.

However, if the air is cooled to only 55°F (13°C), the resulting relative humidity in the space will be about 70%, much higher than the recommended upper limit of 60% (*Figure 1*).

Therefore, the design of the HVAC system for a surgery room must consider temperature and humidity. When using a standard cooling coil, often the air must be cooled to a colder-than-necessary dry-bulb temperature to adequately dehumidify the surgery room.

The latent heat gain equation determines that, to offset the space latent load of 1,600 Btu/h (0.47 kW), the supply air must be delivered at a humidity ratio of 48 gr/lb (6.9 g/kg), which equates to a 47°F (8°C) dew point.

$$Q_L = 0.7 \times 1,125 \text{ cfm} \times (50 \text{ gr/lb} - W_{sa}) = 1,600 \text{ Btu/h} \\ \therefore W_{sa} = 48 \text{ gr/lb}$$

To achieve the design space humidity level, the 1,125 cfm (0.53 m<sup>3</sup>/s [531 L/s]) of supply air must be dehumidified to 47°F (8°C) dew point (CA), which corresponds to a dry-bulb temperature of about 48°F (9°C). However, delivering this quantity of air at this colder-than-necessary dry-bulb temperature will overcool the space, which only requires 55°F (13°C) air to offset the space sensible load.

A common solution to this challenge is to add a reheat coil downstream of the cooling coil. The reheat coil raises the dry-bulb temperature of the dehumidified supply air (SA) to 55°F (13°C) before this air is delivered to the space (*Figure 2*). Using this temperature and humidity design approach meets both the temperature and humidity requirements of the space.

### System Solutions

The rest of this article investigates a few HVAC system configurations that can achieve the temperature and humidity targets for the surgery room by delivering the required supply-air conditions.



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## Solution 1: Cool & Reheat (One Cooling Coil)

Figure 3 illustrates a system configuration that uses a single cooling coil to dehumidify the air, thereby maintaining the required space humidity level. A reheat coil then warms the supply air to maintain the desired space temperature. At design conditions for the same example surgery room, the required cooling capacity is 3 tons (10.6 kW), and the required reheat capacity is 8,500 Btu/h (2.5 kW).

This configuration requires reheating the air, even at design load, to avoid overcooling the space. Although the exceptions in Section 6.5.2.3 of ANSI/ASHRAE/IESNA Standard 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, allow use of new energy for reheat to control humidity in a surgery room,<sup>6</sup> be sure to evaluate the feasibility of using heat recovered from another part of the HVAC system.

This approach likely requires the installation of a new chiller selected to provide water that is cold enough—about 39°F (4°C) for this example—to allow the cooling coil to dehumidify the air to 48°F (9°C). In many cases, the new chiller for the surgery rooms is a stand-alone, air-cooled chiller or a water-cooled chiller plant.

A building (or campus of buildings) that contains surgery rooms usually has relatively few spaces that require supply air with a lower-than-normal dew point. For example, a hospital includes surgery rooms, certain laboratories, and pharmacy prep areas that may require supply air at 35°F to 50°F (2°C to 10°C) dew point. But patient rooms, waiting rooms, office spaces, cafeterias, and service areas seldom need such dry supply air.

Although extra capacity may be available at the facility's existing chilled water plant, the water it supplies may not be cold enough for the cooling coils to adequately dehumidify the surgery rooms. In this example, if the existing plant supplies 45°F (7°C) water, it is unlikely that the coil can cool the leaving air to 48°F (9°C). In this case, a new water-cooled chiller could be selected to provide water that is sufficiently cold, and the water returning to the existing chiller plant could be used as the “condenser water” for the new chiller (Figure 4). The condenser heat rejected by the new chiller is added to the cooling load on the existing chiller plant. The primary benefit of this configuration is no need exists to find space outdoors for a new air-cooled chiller or a new cooling tower.

## Solution 2: Cool & Reheat (Two Cooling Coils in Series)

The second system configuration is similar to the first. However, it uses two cooling coils in series, rather than a single coil (Figure 5). The upstream coil cools and dehumidifies the air to 55°F (13°C)—requiring 1.8 tons (6.3 kW) of capacity—and the downstream coil dehumidifies the air the rest of the way to 48°F (9°C)—requiring 1.2 tons (4.2 kW).

	Dry Bulb	Relative Humidity	Room ACH	Outdoor ACH	Outdoor Air
ASHRAE <sup>1</sup>	68°F–75°F (20°C–24°C)	30%–60%	25	5	20%
AIA <sup>2</sup>	68°F–73°F (20°C–23°C)	30%–60%	15	3	20%
VA <sup>5</sup>	62°F–80°F (17°C–27°C)	45%–55%	15	15	100%

Table 1: Temperature, humidity, and air-change requirements for surgery rooms.

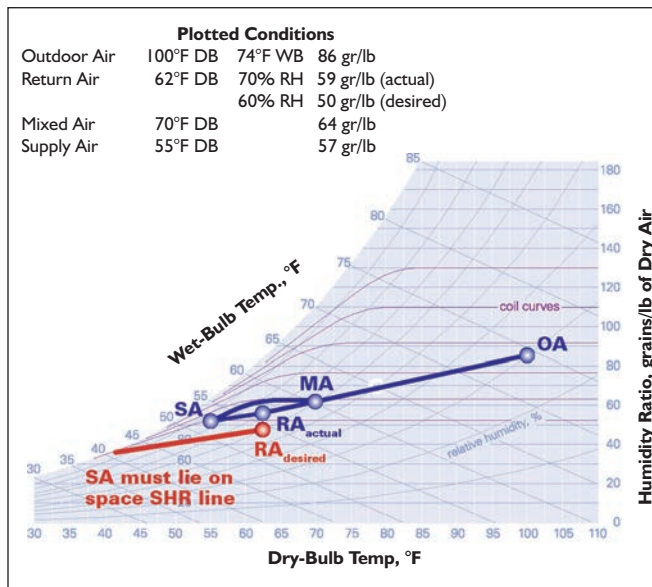


Figure 1: Result of using a temperature-only design approach.

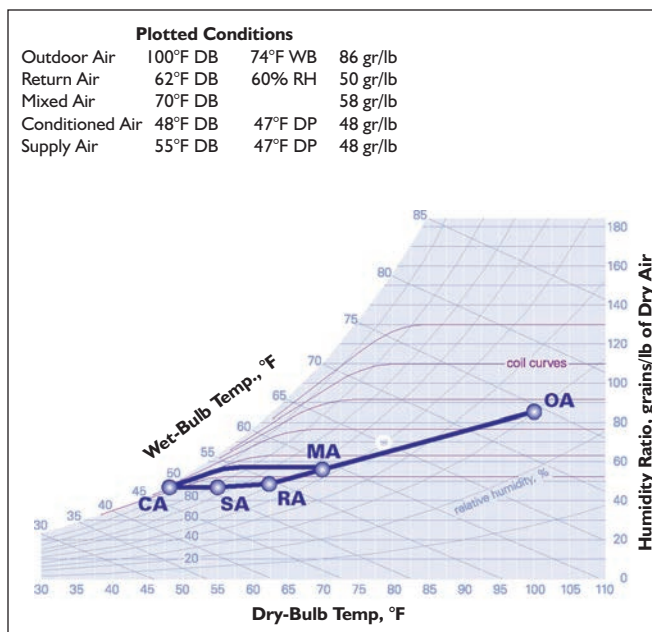


Figure 2: Temperature-and-humidity design approach using reheat.

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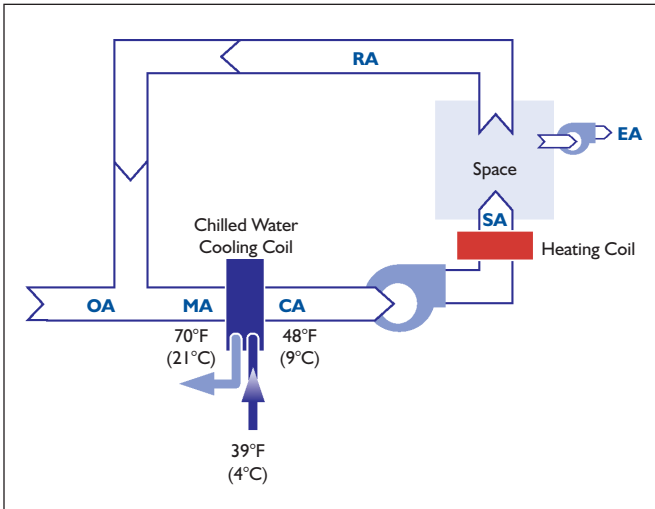


Figure 3: Cool and reheat (single cooling coil).

As in the first configuration, the required reheat capacity is 8,500 Btu/h (2.5 kW).

This option also requires reheat at design load as well as a new chiller capable of providing water cold enough to dehumidify the surgery rooms. The primary benefit of this two-coil approach is that the upstream coil can be served by an existing chilled water plant (assuming it has sufficient capacity available) that wasn't originally designed to supply water cold enough to produce 48°F (9°C) air. Therefore, the new chiller, which serves only the downstream coil, can be smaller than in a system that uses a single cooling coil.

Similar to the single-coil configuration, the downstream cooling coil may be served by a new stand-alone, air-cooled chiller or water-cooled chiller plant, or it can be served by a water-cooled chiller that uses central plant return water for condensing.

### Solution 3: Series Desiccant Wheel

A relatively new system configuration places a desiccant dehumidification wheel in series with a standard cooling coil (Figure 6).<sup>7</sup> The regeneration side of the wheel is located upstream of the cooling coil and the process side is downstream of the coil. The desiccant wheel adsorbs water vapor from the air downstream of the cooling coil, enabling the system to deliver drier supply air (at a lower dew point) without lowering the coil temperature.

The wheel in this configuration uses a Type III desiccant selected specifically for this application. The desiccant's ability to adsorb water vapor is high when the relative humidity of the air is high (Figure 7). As RH decreases, its moisture-holding ability drops significantly. Air leaving an active cooling coil usually exceeds 90% RH. At this condition, the series desiccant wheel can adsorb lots of water vapor from the air. When the wheel

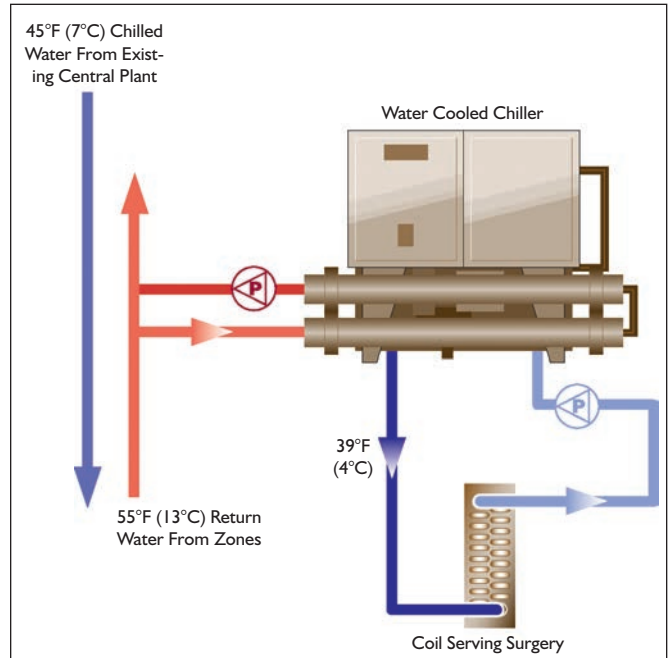


Figure 4: New water-cooled chiller using central plant return water for condensing.

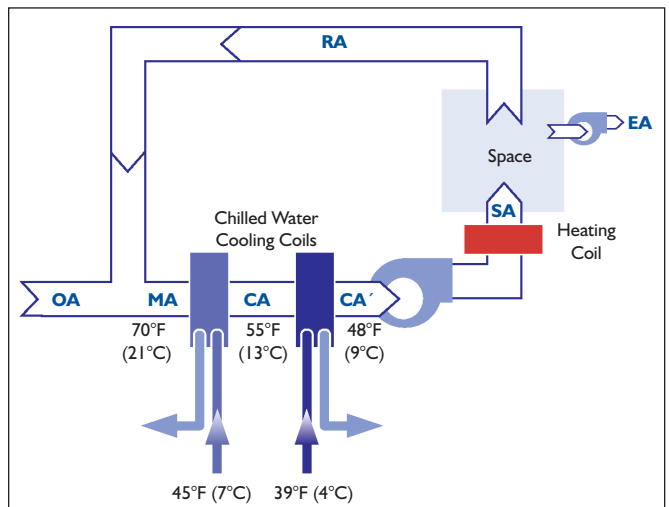


Figure 5: Cool and reheat (two cooling coils in series).

rotates upstream of the cooling coil, it is exposed to air with a lower relative humidity (typically 40% to 60%). At this condition, the desiccant can't retain the water vapor that it collected, so the moisture transfers from the wheel to the passing airstream. This gives the cooling coil a second chance to remove the water vapor via condensation. Moisture transfer occurs within a single airstream. A separate, regeneration airstream isn't needed.

Adsorption isn't driven by hot regeneration air but by the ability of the Type III desiccant to regenerate at low temperatures, often

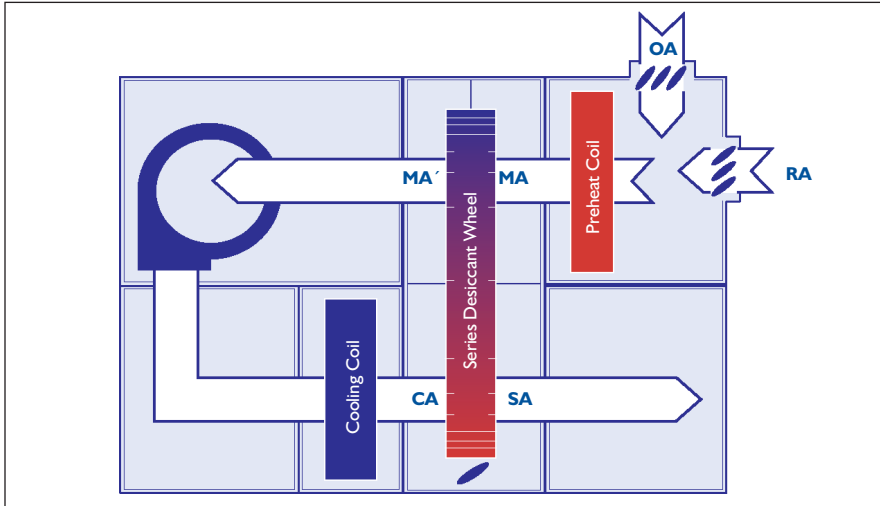


Figure 6: Air handler with series desiccant wheel.

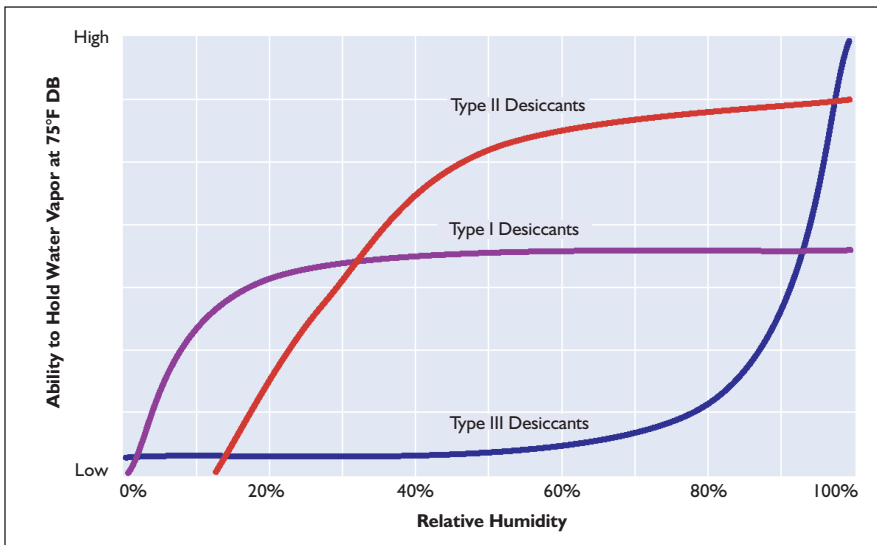


Figure 7: Typical desiccant isotherms.

without supplemental heat. The wheel rotates slowly, maximizing the transfer of water vapor while minimizing sensible heat transfer. The increase in the dry-bulb temperature of the process air is associated only with the amount of heat produced by the adsorption process. This makes the series wheel suitable for use in the mixed airstream—and allows a single unit to both cool and dehumidify the space.

Figure 8 shows the performance of this mixed air system in the same example

surgery room. Air leaves the cooling coil (CA) at a high relative humidity. The series desiccant wheel adsorbs water vapor, drying the supply air (SA) to a dew point of 43°F (6°C). Sensible heat added by the adsorption process raises the supply-air dry-bulb temperature to 55°F (13°C). Mixed air (MA) entering the regeneration side of the wheel is at a lower relative humidity (about 50%). At this RH, water vapor is released from the desiccant into the mixed air (MA'),

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where it can then condense on the cold coil surface. The resulting space condition (RA) for this example is 62°F (17°C) dry bulb and 55% RH.

Basically, adding the series desiccant wheel changes the dehumidification performance of the standard cooling coil, trading sensible capacity for more latent capacity. The latent (dehumidification) capacity of the cooling coil increases while the total cooling capacity (enthalpy change across the coil) remains the same. For this example, the required cooling capacity is 2.1 tons (7.4 kW). However, unlike both cool-and-reheat systems, no reheat is required at design load.

A preheat coil can be added upstream of the regeneration side of the wheel (*Figure 6*) for applications that require even drier air. Activating the preheat coil raises the dry-bulb temperature slightly (5°F to 20°F [3°C to 11°C]) and lowers the relative humidity of the mixed air (MA). Lowering the relative humidity allows the desiccant to reject more water vapor to the regeneration air, thus enabling it to adsorb more water vapor from the process air. In many cases, the small amount of heat added by the preheat coil can be recovered from the condensing process of the refrigeration equipment.

To deliver the same supply-air (SA) condition using either of the cool-and-reheat systems, the cooling coil(s) must cool the air to nearly 48°F (9°C) dry bulb to achieve a 47°F (8°C) dew point. Then the reheat coil must raise the dry-bulb temperature to 55°F (13°C) to avoid overcooling the space (*Figure 2*). By contrast, the series desiccant wheel can deliver the same dew point using less cooling capacity, no reheat, and a warmer leaving-coil temperature—52°F (11°C) vs. 48°F (9°C). This warmer coil enables more efficient mechanical cooling (a higher suction temperature in DX equipment, warmer water or a lower flow rate in chilled water systems). These benefits, of course, must be analyzed to see that they outweigh the impact of the added airside pressure drop due to the wheel.

If sufficient capacity is available at the existing central chiller plant, proper cooling coil selection could allow the existing 45°F (7°C) water to produce 52°F (11°C) air leaving the coil (CA), thereby eliminating the need for a separate chiller (*Figure 9*).

If the chiller plant does not have adequate capacity, the new chiller serving the surgery rooms can be selected for a

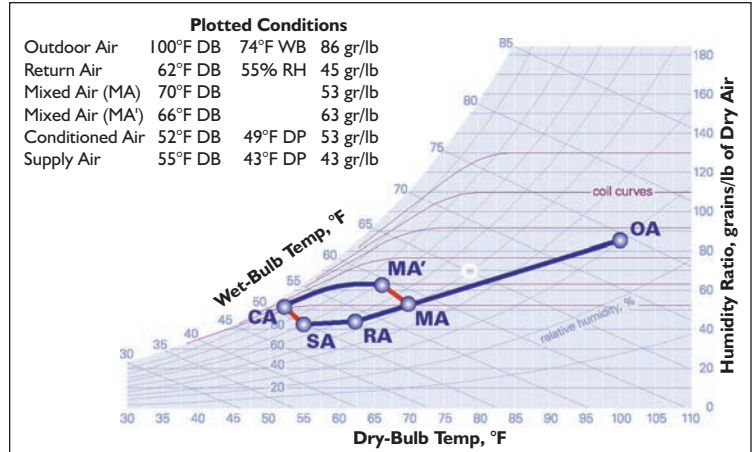


Figure 8: Series desiccant wheel serving surgery room.

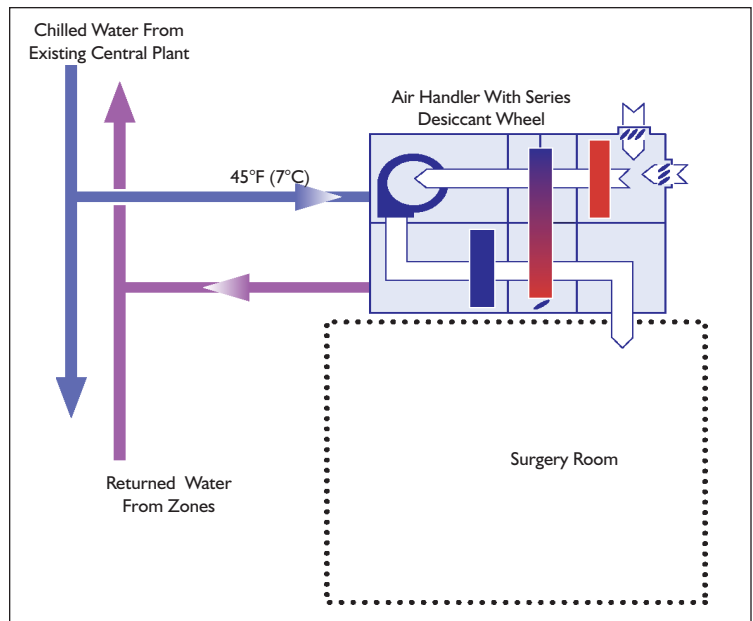


Figure 9: Air handler with series desiccant wheel served by existing central plant.

	Space RH	Cooling Capacity	Leaving-Coil DB	Reheat Capacity
Cool and Reheat (Single Cooling Coil)	60%	3 tons (10.6 kW)	48°F (9°C)	8,500 Btu/h (2.5 kW)
Cool and Reheat (Two Cooling Coils In Series)	60%	3 tons (10.6 kW)		8,500 Btu/h (2.5 kW)
Upstream Cooling Coil		1.8 tons (6.3 kW)	55°F (13°C)	
Downstream Cooling Coil		1.2 tons (4.2 kW)	48°F (9°C)	
Series Desiccant Wheel	55%	2.1 tons (7.4 kW)	52°F (11°C)	0 Btu/h (0 kW)

Table 2: System comparisons at design load.

warmer supply-water temperature than for the cool-and-reheat systems. Alternatively, the 52°F (11°C) leaving air may be achievable using standard direct-expansion (DX) cooling equipment.

### Conclusions

It is important to consider both temperature and humidity when designing the HVAC system for a surgery room. Using a rule of thumb or a temperature-only design approach often leads to a system that is unable to meet both requirements, especially when the surgeon lowers the thermostat setpoint.

System solutions that can meet both temperature and humidity requirements may require new equipment, make use of an existing central plant, or a combination. *Table 2* compares the three solutions discussed in this article.

The series desiccant wheel is able to deliver drier air (at a lower dew point) without lowering the coil temperature. An existing chiller plant might be able to provide all of the cooling capacity because the temperature of the air leaving the cooling coil can be warmer than in the cool-and-reheat systems. Alternatively, if the cooling equipment serving the surgery rooms is separate from the existing chiller plant, the series desiccant wheel system requires less overall cooling capacity and no reheat at design load.

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