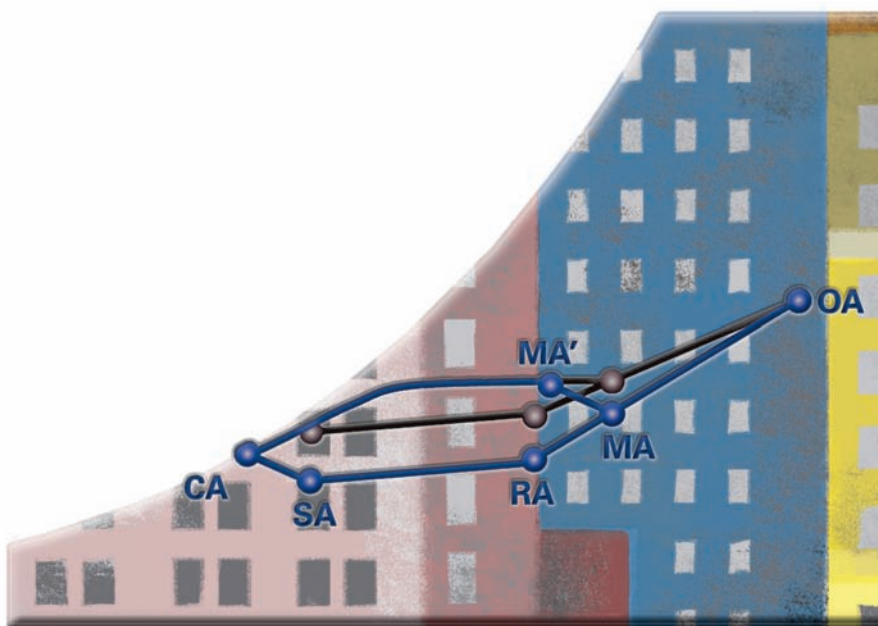


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Using VAV To Limit

Humidity at Part Load



By John Murphy, Member ASHRAE

High humidity levels can reduce the quality of indoor air, make occupants uncomfortable, and damage a building's structure and furnishings. To avoid problems associated with high humidity levels, it's important to understand how well an HVAC system will dehumidify at both full load and part load. But, part-load dehumidification performance varies by system type and control strategy.

A previous article¹ demonstrated the challenge of dehumidifying with a basic, constant volume (CV) system, such as a packaged terminal air conditioner, small packaged rooftop unit, small DX split system, water-source heat pump, or fan-coil unit. A basic CV system supplies a single zone with a constant quantity of air regardless of the cooling load. As the sensible cooling load decreases, this system delivers ever warmer (and, therefore, wetter) supply air to avoid overcooling the

zone, and dehumidification performance suffers.

Fortunately, with proper system design and control, HVAC systems can dehumidify better over a wide range of conditions—and do so cost effectively and efficiently. Strategies such as multiple-speed fan control, variable airflow, reheat using heat recovered from the refrigeration system (such as hot gas reheat or condenser-water heat recovery), reheat using an air-to-air heat exchanger (such

as a fixed-plate heat exchanger, coil loop, or heat pipe), passive or active desiccant dehumidification wheels, and dedicated outdoor air systems (DOAS) can all improve the dehumidification performance of an HVAC system.^{1,2} The right choice for a given project depends on the climate, building use and configuration, available budget, and operating cost goals.

The focus of this article is on the dehumidification performance of one common type of HVAC system that is used to provide comfort in a range of building types and climates—a variable air volume (VAV) system.

Dehumidification Performance

A typical VAV system consists of a central air-handling unit, or packaged

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rooftop unit, that serves several individually controlled zones, each having a VAV terminal unit. A sensor compares the dry-bulb temperature in the zone to a setpoint, and the VAV terminal varies the quantity of air delivered to that zone to maintain the desired temperature.

Unlike a constant volume system, which delivers a constant quantity of air at varying temperatures, a VAV system delivers a varying quantity of constant-temperature air, typically between 45°F and 55°F dry-bulb temperature (DBT) (7°C to 13°C DBT).

VAV systems typically dehumidify reasonably well over a wide range of indoor loads because they supply air at a relatively constant, low dew-point temperature at all load conditions. As long as any zone needs cooling, the VAV air-handling unit supplies air at a dew point that is usually low enough (sufficiently cool and dry) to maintain indoor humidity levels within a reasonable range.

To demonstrate, consider an example 30-person classroom in Jacksonville, Fla. The HVAC system is designed to deliver 1,500 cfm (709 L/s) of supply air to this zone, of which 450 cfm (212 L/s) is outdoor air required for ventilation.

Plotting this system on a psychrometric chart (Figure 1), this conventional VAV system mixes outdoor air (OA) with the recirculated return air (RA). This mixed air (MA) passes through the cooling coil before being delivered to the zones as supply air (SA).

At the traditional design condition (peak outdoor dry-bulb temperature), the VAV system delivers 1,500 cfm (709 L/s) of air to this example classroom. This supply air is delivered at about 55°F (13°C) to offset the sensible cooling load in the zone and maintain the zone temperature at the desired setpoint of 74°F (23°C). This cool, dry supply air absorbs sensible heat and moisture (latent heat) from within the zone and, in this example, maintains the relative humidity (RH) in the zone at 52% (Figure 1).

At part-load conditions, the space sensible cooling load is less than at design conditions. The VAV system responds by reducing the quantity of air supplied to avoid overcooling the zone, while maintaining a relatively constant supply air temperature (55°F [13°C] in this example). At this example part-load (peak outdoor dew-point temperature) condition, supply airflow is

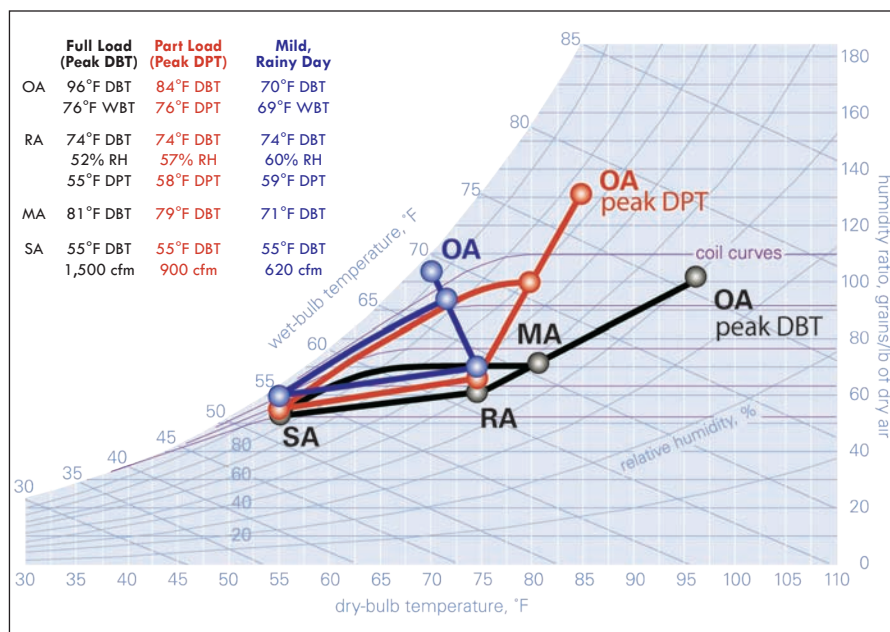


Figure 1: Dehumidification performance of a basic variable air volume (VAV) system.

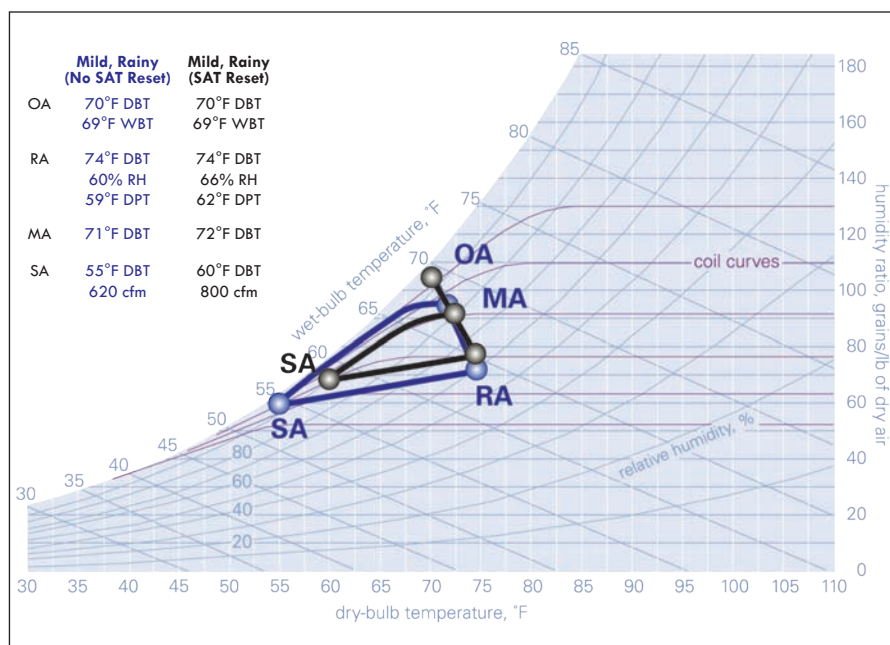


Figure 2: Impact of supply air temperature (SAT) reset on indoor humidity levels.

reduced to 900 cfm (425 L/s). Because the supply air is still cool and dry (low dew point), however, the relative humidity in the classroom only rises to 57% (Figure 1), compared to 52% at design conditions.

Now, consider a cool, rainy day—70°F dry bulb, 69°F wet bulb (21°C DBT, 20.6°C WBT), for example. At this condition, the space sensible cooling load decreases even further. The VAV system responds by reducing supply airflow to 620 cfm (293 L/s), while the supply air temperature is still 55°F (13°C). At this condition, the relative humidity in the classroom rises to about 60% (Figure 1).

By continuing to supply cool, dry (low dew point) air at part load, VAV systems typically can dehumidify reasonably well over a wide range of conditions. This performance is often sufficient for many applications in many climates. However, if lower indoor humidity levels are required, several ways to improve the dehumidification performance of a VAV system will be discussed later in this article.

SA Temperature Reset

In many VAV systems, it may be tempting to raise the supply air temperature (SAT) at part-load conditions in an attempt to save cooling or reheat energy. But, in non-arid climates, this warmer supply air results in less dehumidification at the coil and higher indoor humidity levels. And, because the supply air is warmer, those zones that require cooling will need *more* air to offset the cooling load, which increases supply fan energy.³

Using the same classroom example, if the supply air temperature is raised from 55°F (13°C) to 60°F (16°C) on the mild rainy day, 800 cfm (378 L/s) of supply air is required to offset the sensible cooling load in the zone. But this warmer supply air temperature means that the cooling coil removes less moisture from the air. As a result, the relative humidity in the zone rises to 66% (see Figure 2, Page 19), compared to 60% if SAT reset is not used.

If dehumidification is a concern, consider either 1) providing an outdoor dew-point sensor to disable SAT reset when it is humid outside, or 2) providing one or more zone humidity sensors to override the SAT reset sequence if humidity in the zone (or return air) exceeds a maximum limit.

Improving VAV Dehumidification

Even though VAV systems often dehumidify reasonably well over a wide range of conditions, lower indoor humidity levels are sometimes required. Some ways to improve dehumidification performance of a VAV system include:

Colder Supply Air

Lowering the dry-bulb temperature of the air leaving the cooling coil causes more moisture to condense out of the supply air. In a VAV system, this colder, drier supply air results in a drier zone (lower humidity) at all load conditions.

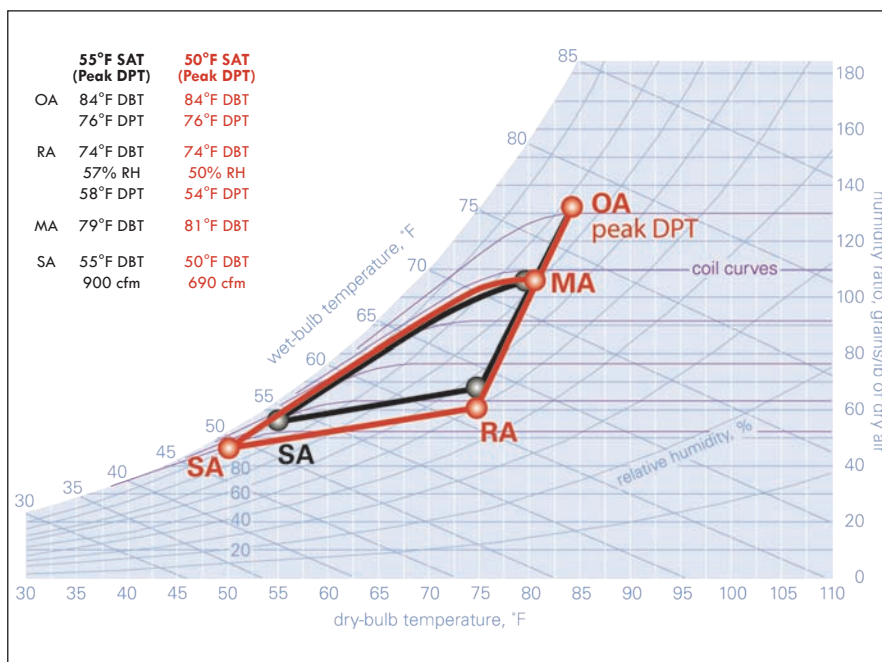


Figure 3: Dehumidification performance of a cold air VAV system.

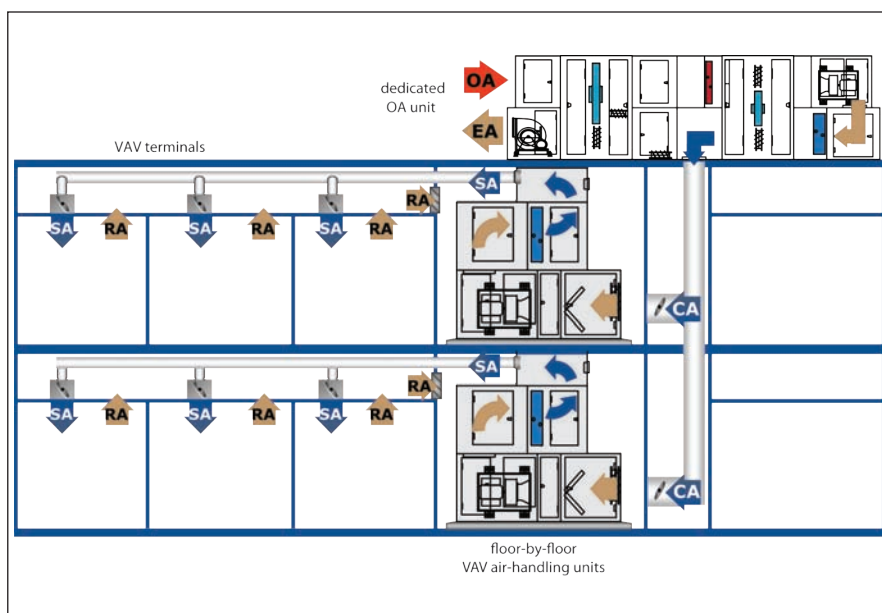


Figure 4: Dedicated outdoor air system used with floor-by-floor VAV air-handling units.

Figure 3 demonstrates the dehumidification impact of using a cold-air VAV system for this same example classroom. In this case, the VAV system is designed to supply air at 50°F (10°C). At the peak dew-point temperature condition, this zone requires only 690 cfm (326 L/s) of supply air. This colder, drier supply air results in a zone relative humidity of 50%, compared to 57% with the conventional (55°F [13°C] supply air) VAV system.

Another benefit of a cold-air VAV system is reduced supply airflow, which can allow for the use of smaller air-handling units, VAV terminals, and ductwork, and can result in significant fan

energy savings. Increased reheat energy and fewer hours of airside economizer operation can partially offset the fan energy savings. Therefore, the use of SAT reset at part-load conditions is important to maximize energy savings.^{3,4}

Dedicated Outdoor Air System

Another way to improve the dehumidification performance of a VAV system is to use a dedicated outdoor air system. This approach uses a separate unit to dehumidify all of the outdoor air to a dew point that is drier than the zones. Then, this dehumidified outdoor air is either:

- Ducted directly to each zone;
- Ducted directly to individual, dual-duct VAV terminals that serve each zone; or
- Ducted to the outdoor-air intake of one or more VAV air-handling units.

Each of these three configurations has its own advantages and disadvantages.^{2,3} The example depicted in *Figure 4* (see facing page) shows the dedicated outdoor air system delivering the dehumidified outdoor air (CA) to floor-by-floor VAV air-handling units. The example dedicated outdoor air unit depicted in this figure includes a total-energy wheel to precondition the entering outdoor air and a series desiccant wheel to enable the unit to deliver drier air without requiring a significantly colder leaving-coil temperature.⁵

A dual-path air-handling unit is similar in concept to a dedicated outdoor air system (*Figure 5*). The outdoor air and recirculated air paths each include a dedicated cooling coil, but the same supply fan serves both air paths. The top coil dehumidifies all of the outdoor air to a dew point that is drier than the zones. The lower coil provides any additional cooling needed to offset the sensible load.

To minimize footprint, one air path can be situated above the other by using a stacked arrangement.

Series Desiccant Wheel

Figure 6 depicts a VAV air-handling unit with a desiccant dehumidification wheel configured in series with the cooling coil.⁵ The desiccant wheel adsorbs water vapor from the air downstream of the cooling coil and then releases the collected moisture upstream of that coil, enabling the air-handling unit

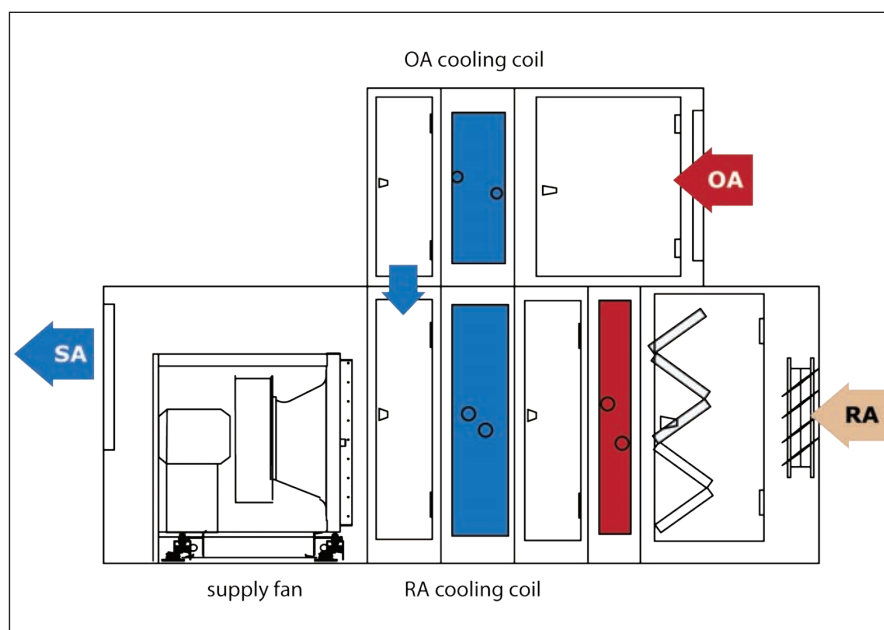


Figure 5: A dual-path VAV air-handling unit.

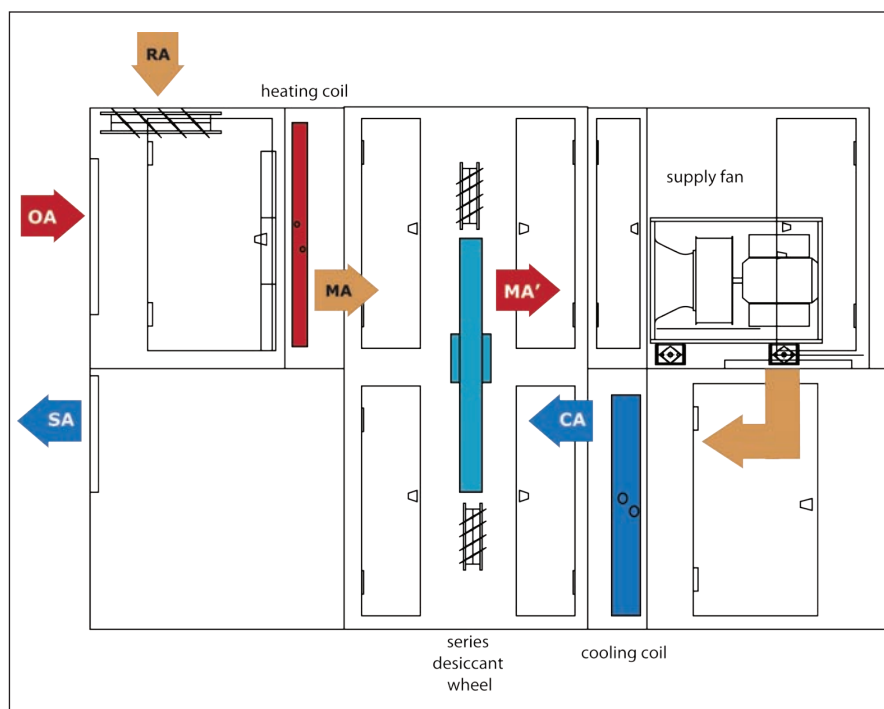


Figure 6: VAV air-handling unit with a series desiccant wheel.

to deliver drier supply air (SA) (at a lower dew point) without needing to lower the leaving-coil temperature. In addition, the moisture transfer occurs within a single airstream; a separate, regeneration airstream is not needed.

Figure 7 shows the dehumidification performance of a VAV system with a series desiccant wheel. Air leaves the cooling coil (CA) at a dry-bulb temperature of 51°F (11°C) and a dew point of 50°F (10°C). The series desiccant wheel adsorbs water vapor, drying the supply air to a dew point of 43°F (6°C). Sensible heat

added by the adsorption process raises the dry-bulb temperature of the supply air to 55°F (13°C). The wheel rotates into the mixed airstream (MA), where water vapor released from the wheel passes into the mixed air (MA') and then condenses on the cold coil surface. Using the same classroom example, delivering the supply air at a dew point of 43°F (6°C) results in 40% RH in the zone.

Adding the series desiccant wheel allows the system to deliver drier air (lower DPT) without requiring a significantly colder leaving coil temperature—without the desiccant wheel, the cooling coil would need to cool the air to nearly 43°F (6°C) dry bulb to achieve a supply-air dew point of 43°F (6°C).

Summary

VAV systems typically dehumidify reasonably well over a wide range of indoor loads. As long as any zone needs cooling,

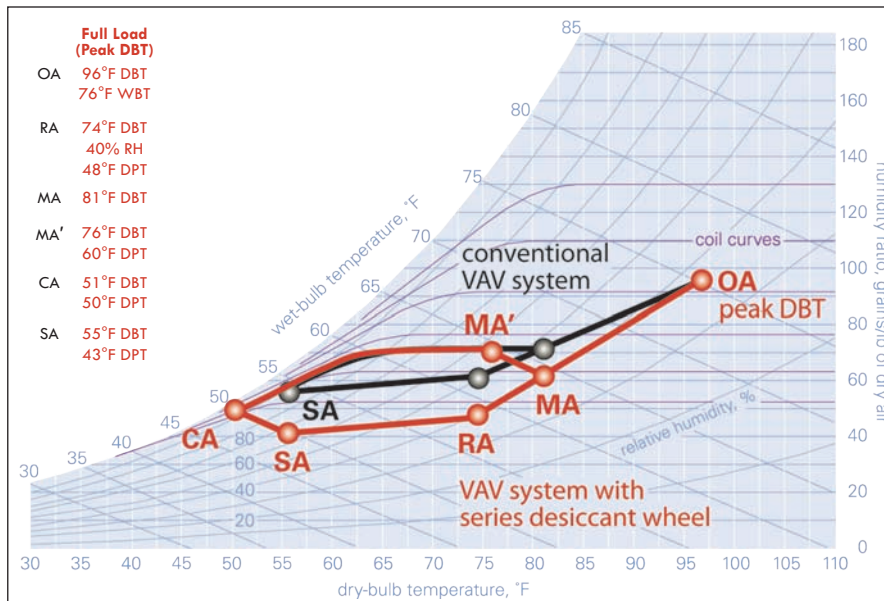


Figure 7: Dehumidification performance of a series desiccant wheel.

the VAV air-handling unit supplies air at a dew point that is usually low enough (suf-

ficiently dry) to maintain indoor humidity levels within a reasonable range.

Avoid using supply air temperature reset during humid weather. Warmer supply air means less dehumidification at the coil and higher humidity levels in the zone. It also increases supply fan energy use—perhaps enough to negate any cooling energy saved.

When required, colder supply air, a dedicated outdoor air system, a dual-path air-handling unit, or a series desiccant wheel can all be used to improve the dehumidification performance of a VAV system.³ The right approach for a given project depends on climate, building use, available budget, and operating cost goals.

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