Application Guide

Dedicated Outdoor Air Systems

Trane DX Outdoor Air Unit

October 2019

SYS-APG001A-EN

Preface

For more information on dedicated outdoor air systems (DOAS), refer to the following:

- *Dehumidification in HVAC Systems*, Trane application manual (SYS-APM004-EN)
- "Dedicated Outdoor Air Equipment," Trane *Engineers Newsletter Live* program (DVD; APP-CMC043-EN)
- *Water-Source and Ground-Source Heat Pump Systems*, Trane application manual (SYS-APM010-EN)
- "Dedicated Outdoor Air Systems" ASHRAE webcast, 2012 (www.ashrae.org)

As a leading HVAC manufacturer, we deem it our responsibility to serve the building industry by regularly disseminating information that promotes the effective application of building comfort systems. For that reason, we regularly publish educational materials, such as this one, to share information gathered from laboratory research, testing programs, and practical experience.

This guide discusses HVAC systems that use:

- a dedicated outdoor air unit to treat all of the outdoor air brought into the building for ventilation, and ...
- zone-mounted terminal units to treat the indoor air.

Treating the outdoor air *separately* from recirculated return air makes it easy to verify sufficient ventilation airflow and enables enforcement of a maximum humidity limit in occupied zones.

Trane, in proposing these system design and application concepts, assumes no responsibility for the performance or desirability of any resulting system design. Design of the HVAC system is the prerogative and responsibility of the engineering professional.

Trademarks

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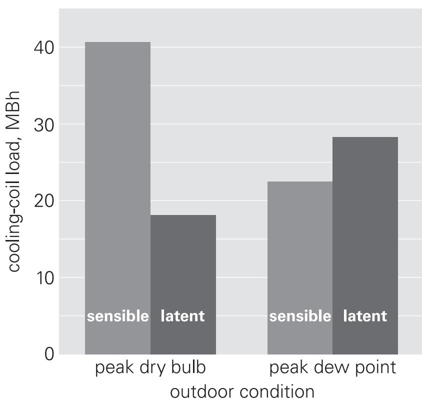
Defining the Dehumidification Challenge

Building professionals expend much time and effort to design HVAC systems that handle both ventilation and dehumidification. High-occupancy spaces, such as classrooms, pose a particular challenge — especially when the system of choice delivers a constant-volume mixture of outdoor and recirculated return air. Why? The answer lies in the fact that the *sensible- and latent-cooling loads on the HVAC equipment do not peak at the same time*.

Figure 1. Cooling loads at different outdoor conditions*



* Based on an example classroom, which is located in Jacksonville, Fla., and has a target space condition of 74°F dry bulb and 50% relative humidity

When it's hot outside, the sensible-cooling load often far exceeds the latent-cooling load (Figure 1). By contrast, when it's cooler but humid outside, the latent-cooling load can approach or even exceed the sensible-cooling load.

Conventional HVAC equipment traditionally is *selected* with sufficient cooling capacity to handle the design load at the peak outdoor dry-bulb condition and *controlled* by a thermostat that matches the sensible-cooling capacity of the coil with the sensible-cooling load in the space. Therefore, as the sensible-cooling load in the space decreases, the cooling capacity (both sensible and latent) provided by the HVAC equipment also decreases. In most climates, the combination of less latent-cooling capacity and a lower SHR (sensible-heat ratio) in the space elevates the indoor humidity level at part-load conditions.

An "off-the-shelf," packaged unitary air conditioner may further aggravate this situation. Such equipment is designed to operate with a supply-airflow-to-cooling-capacity ratio of 350 to 400 cfm/ton. In hot, humid climates, offsetting the ventilation load for high-occupancy spaces may require that the unit delivers no more than 200 to 250 cfm/ton in order to achieve the dew point needed for adequate dehumidification.

Dedicated OA System Configurations

One way to successfully limit indoor humidity levels is to use a **dedicated outdoor air system (DOAS)**. The design approach outlined in this guide permits each component of the HVAC system to do what it does best: *Zone-level heating-and-cooling equipment* provides occupants with air circulation and thermal comfort by modulating the cooling-coil capacity to match the sensible-cooling load in the space. Any local latent cooling occurs coincidentally; the latent-cooling load does not affect the selection of zone-level HVAC equipment. Meanwhile, a *central, dedicated outdoor air unit* sufficiently dehumidifies the outdoor air to meet both the latent-cooling load and the ventilation requirements for all spaces served by the system.

Dividing the building's cooling load in this fashion can make it easier to effectively ventilate and dehumidify occupied spaces. Key concepts to remember when undertaking such a design include the following:

- **Always provide conditioned air that is drier than the air in the space.** This practice minimizes the cooling capacity required from the local HVAC terminals and adequately controls the indoor humidity without additional, zone-level dehumidification enhancements.
- **Deliver "cold" conditioned air whenever possible, and use recovered energy to reheat during mild weather.** Providing "cold" conditioned air from the DOAS minimizes the cooling loads at the local HVAC terminals. During mild weather (spring and fall), modulate the amount of recovered energy used by the DOAS for reheat; only warm the dehumidified air enough to avoid overcooling the zones.

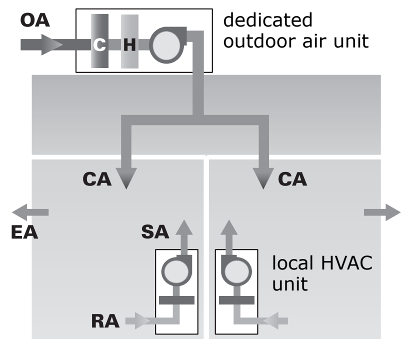
  "Neutral"-temperature conditioned air (which has a dry-bulb temperature approximating that of the air in the space) increases the cooling capacity required from the local HVAC terminals and requires more reheat at the dedicated outdoor air unit.
- **Deliver the conditioned outdoor air directly to each occupied space, whenever possible.** This helps ensure that the required amount of outdoor airflow reaches each occupied space, allows the conditioned OA to be delivered at a "cold" temperature (rather than reheated to neutral), simplifies the application of demand-controlled ventilation (when desired), and allows the fans in the local HVAC equipment to cycle off without affecting ventilation performance.

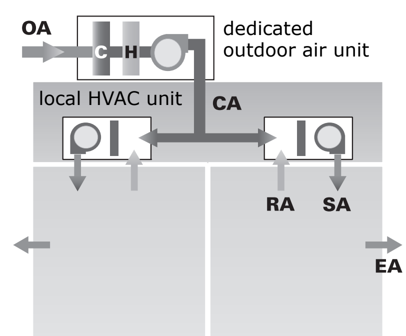
Dedicated outdoor air systems can be designed to deliver conditioned outdoor air either directly to each occupied space or to the individual HVAC terminals or air handlers serving those spaces. Evaluate the advantages and disadvantages of each configuration when designing a DOAS application.

Table 1 summarizes the advantages and drawbacks of each configuration.

Table 1. Comparison of different dedicated OA system configurations

<table>
<tr><th colspan="2">Conditioned OA delivered directly to each space</th></tr>
<tr><td>The DOAS in Figure 2 consists of a dedicated outdoor air unit, which delivers conditioned outdoor air (CA) to each occupied space via separate ductwork and diffusers. The local HVAC equipment conditions only recirculated air (RA). This configuration accommodates a wide variety of local equipment, including water-source heat pumps, vertical or horizontal fan–coils, unit ventilators, DX (direct-expansion) rooftop units, split systems, blower–coils, through-the-wall air conditioners (PTACs), variable-refrigerant-flow (VRF) terminals, passive chilled beams, and radiant cooling surfaces.</td><td>Figure 2.


</td></tr>
<tr><td>Advantages:</td><td>Disadvantages:</td></tr>
<tr><td>• Makes it easier to ensure the required amount of outdoor air reaches each zone, because separate ventilation diffusers allow easy airflow measurement and balancing
• Affords opportunity to cycle off, or vary the speed of, the fan inside the local unit (reducing fan energy use) when no cooling or heating is required, because outdoor air is not distributed to the zone by the local fan
• Allows the dedicated OA system to operate during unoccupied periods (for after-hours humidity control or preoccupancy purge, for example) without needing to operate the fans inside the local units
• Affords the opportunity to downsize local units (reducing installed cost and energy use) if the conditioned outdoor air is delivered at a cold temperature (rather than reheated to “neutral”)</td><td>• Requires installation of additional ductwork and separate diffusers
• May require multiple diffusers to ensure that outdoor air is adequately dispersed throughout the zone</td></tr>
<tr><th colspan="2">Conditioned OA delivered to the intake of each local HVAC unit</th></tr>
<tr><td>The DOAS in Figure 3 also uses a dedicated outdoor air unit to handle the ventilation load. Ductwork carries the conditioned outdoor air (CA) to each local HVAC terminal or air handler (typically blower–coils, horizontal fan–coils, or water-source heat pumps), discharging it near or directly into the inlet. The conditioned outdoor air then mixes with recirculated return air (RA) and passes through the cooling coil of the local terminal (or air handler), which delivers the mixed supply air (SA) to the space.</td><td>Figure 3.


</td></tr>
<tr><td>Advantages:</td><td>Disadvantages:</td></tr>
<tr><td>• Helps ensure the required amount of outdoor air reaches each local unit, because the OA is ducted directly to each intake
• Avoids the cost and space needed to install additional ductwork and separate diffusers
• Easier to ensure that outdoor air is adequately dispersed throughout the zone, because outdoor air is distributed by the local fan</td><td>• Measurement and balancing is more difficult than if the OA was delivered directly to the zone via separate diffusers
• May require a field-fabricated plenum or section of duct to connect the outdoor air duct and mix it with recirculated air prior to entering the local HVAC unit
• Fans inside the local units must operate continuously to provide ventilation during scheduled occupancy, rather than cycling off
• If the dedicated OA system operates during unoccupied periods (for after-hours humidity control or preoccupancy purge, for example), the fans inside the local units typically must operate also</td></tr>
</table>

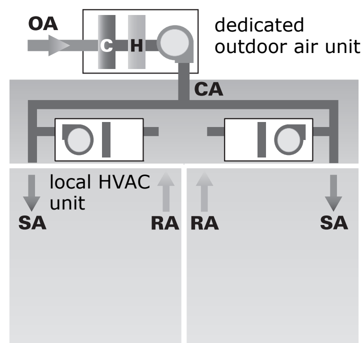
Dedicated OA System Configurations

Table 1. Comparison of different dedicated OA system configurations (continued)

Conditioned OA delivered to the supply-side of each local HVAC unit

The DOAS in Figure 4 delivers the conditioned outdoor air (CA) directly to the supply-side of each local HVAC terminal, where it mixes with supply air from the local HVAC terminal before being delivered to the occupied space. The local equipment conditions only recirculated air (RA).

Figure 4.

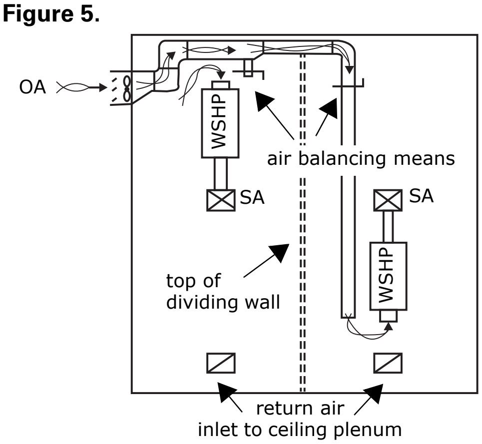


Advantages:	Disadvantages:
• Helps ensure the required amount of outdoor air reaches each unit, because the OA is ducted directly to the supply-side of each unit • Avoids the cost and space needed to install additional ductwork and separate diffusers • Affords the opportunity to downsize local units (reducing installed cost and energy use) if the conditioned outdoor air is delivered at a cold temperature (rather than reheated to "neutral") • Easier to ensure that outdoor air is adequately dispersed throughout the zone, because outdoor air is distributed by the local fan	• Measurement and balancing is more difficult than if the OA was delivered directly to the zone via separate diffusers • Fans inside the local units typically must operate continuously to provide ventilation during scheduled occupancy, rather than cycling off (unless a pressure-independent VAV terminal is used to maintain outdoor airflow)

Conditioned OA delivered to the open ceiling plenum, near each local HVAC unit

The DOAS in Figure 5 delivers the conditioned outdoor air (CA) to the ceiling plenum, near the intake of each local HVAC terminal. The outdoor air mixes with recirculated air (RA) in the plenum before being drawn in through the intake of the unit. The local unit conditions this mixture of outdoor and recirculated air, and delivers it to the occupied space through a shared duct system and diffusers.

Figure 5.



Source: ASHRAE *62.1-2016 User's Manual,* Figure 5-D ©American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, www.ashrae.org.

Advantages:	Disadvantages:
• Avoids the cost and space needed to install additional ductwork, separate diffusers, or field-fabricated mixing plenums	• More difficult to ensure the required amount of outdoor air reaches each unit, since the OA is not ducted directly to each local unit (refer to the *ASHRAE 62.1 User's Manual* for further guidance) • Conditioned outdoor air may not be able to be delivered at a cold temperature, due to concerns over condensation within the ceiling plenum (rather, it must typically be reheated closer to a "neutral" temperature) • Fans inside the local units must operate continuously to provide ventilation during scheduled occupancy, rather than cycling off • If the dedicated OA system operates during unoccupied periods (for after-hours humidity control or preoccupancy purge, for example), the fans inside the local units typically must operate also

Cold or Neutral Air?

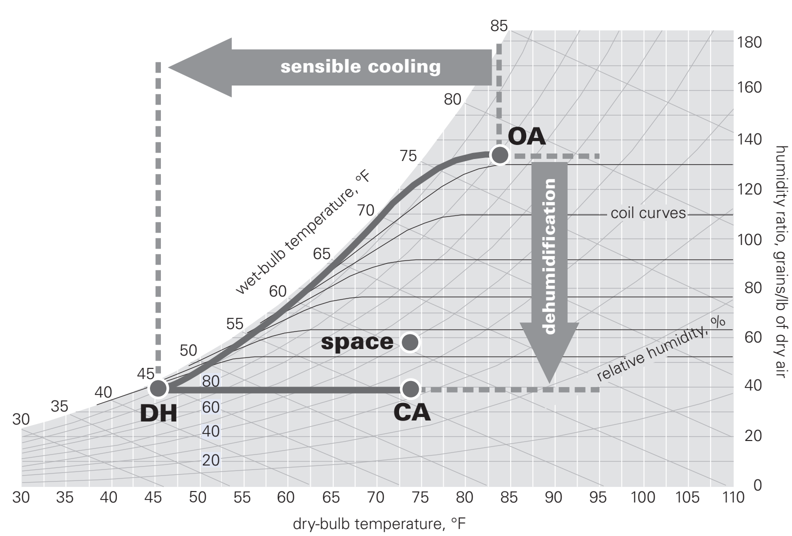
Regardless of where the conditioned outdoor air is delivered, the dedicated OA unit should dehumidify the outdoor air so that it is drier than the zone. This offsets the latent load associated with ventilation and, if the dew-point temperature of the conditioned outdoor air is lower than the dew point in the zone (Figure 6), also offsets some (or all) of the zone latent loads. This approach can adequately limit indoor humidity levels, at both full- and part-load conditions, without the need for additional dehumidification enhancements in the local HVAC equipment.

Many dedicated OA systems are designed to dehumidify the outdoor air and then reheat it to approximately zone temperature (neutral). Delivering the dehumidified outdoor air at a neutral dry-bulb temperature can simplify control because it has no impact on the zone sensible cooling or heating loads.

However, when a chilled-water or DX cooling coil is used for dehumidification, a by-product of that process is that the dry-bulb temperature of the air leaving the coil is colder than the zone (Figure 6). If the dehumidified outdoor air (DH) is reheated to neutral (CA), most of the sensible cooling performed by the dedicated OA unit is wasted.

If the dedicated OA system delivers air directly to each zone (see Figure 2, p. 3) or to the supply-side of each local HVAC unit (see Figure 4, p. 4), the dehumidified outdoor air (DH) can be delivered “cold,” rather than reheated to neutral. The low dry-bulb temperature of the conditioned OA offsets part of the sensible cooling load in the zone, reducing the energy used by the local unit. At design conditions, this means that the local unit can be sized for less airflow and less cooling capacity than in a neutral-air system.

Figure 6. Sensible cooling is a by-product of 'cold-coil' dehumidification



Compared to a neutral-air system, a dedicated OA system that delivers cold air directly to each zone or to the supply-side of each local HVAC unit:

- **Requires less overall cooling capacity**
  The required capacity of the dedicated OA unit is the same for both configurations, but the required cooling capacity of each local unit is less in a cold-air system than in a neutral-air system.
- **Requires less overall cooling energy for much of the year**
  By taking advantage of the sensible cooling already done by the dedicated OA unit, the cold-air system requires less cooling energy at each local unit. The neutral-air system throws away this sensible cooling benefit by reheating the air to approximately zone temperature.
- **Requires less overall fan airflow and, therefore, less fan energy**
  The airflow delivered by the dedicated OA unit is the same for both configurations, but for those zones that require seasonal cooling and heating, the supply airflow delivered by the local HVAC unit is less in a cold-air system than in a neutral-air system. (For zones that require year-round cooling, the local HVAC equipment may not be able to be downsized as much, since it may need to be sized based on the warmest temperature expected to be delivered by the dedicated OA unit.)

While the conditioned outdoor air should be delivered cold whenever possible, there are situations when the dedicated OA unit should reheat the dehumidified outdoor air:

- **To avoid overcooling at part-load conditions**
  As explained earlier, delivering the conditioned OA at a dry-bulb temperature colder than the zone temperature offsets part of the sensible cooling load in the zone. As the zone sensible cooling load decreases—due to changes in outdoor conditions, solar heat gain, and/or internal loads—it is possible that the cold, conditioned OA may provide more sensible cooling than the zone requires. As a result, the temperature in the zone begins to drop. At these conditions, depending on the type of local HVAC equipment being used, it may be desirable to heat (or reheat) the outdoor air before delivering it directly to the zones.

  For many applications, a better approach to avoid overcooling is to implement demand-controlled ventilation. This control strategy reduces the quantity of outdoor air delivered to a zone when there are fewer people in that zone. This often avoids overcooling altogether, and reduces the energy used to condition and deliver that air.
- **In applications where zone sensible cooling loads differ greatly at any given time**
  In hotel guest rooms or dormitories, the sensible cooling loads can be drastically different from zone to zone. The result is that, if the conditioned OA is delivered cold, it may be more likely that some zones will experience overcooling. For these applications, it may be simpler to deliver the conditioned OA at a neutral dry-bulb temperature because the benefit of delivering the air cold occurs less frequently.

  In classrooms or offices, however, sensible cooling loads in the zones are relatively high during daytime hours. In fact, for some climates, classrooms may never reach the point when overcooling occurs during occupied hours, especially if demand-controlled ventilation is used to reduce outdoor airflow when zone population decreases. These applications are typically well-suited for delivering the conditioned OA at a cold temperature.

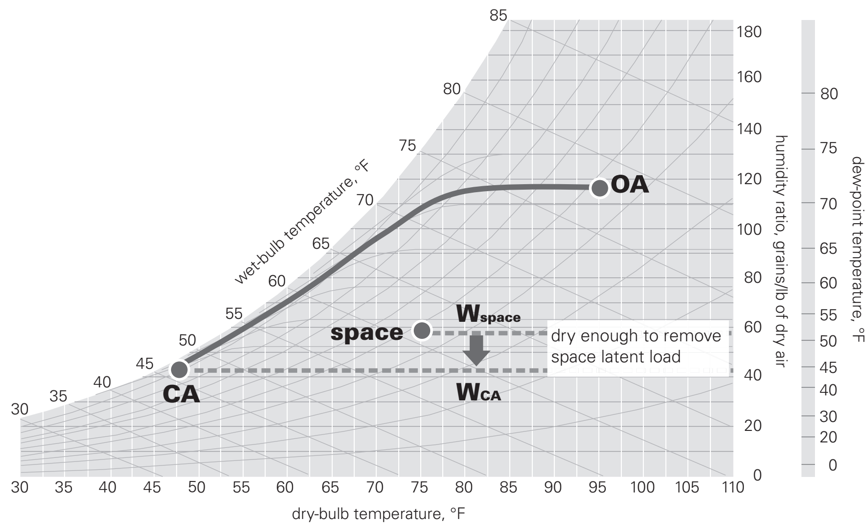
- **In applications that require low dew points**
  If an application has very high indoor latent loads the outdoor air may need to be dehumidified to a very low dew point. In this case, the corresponding dry-bulb temperature of the air leaving the cooling coil may be colder than the HVAC design engineer is willing to discharge directly into an occupied zone—below 45°F (7°C), for example. In this case, the dehumidified OA could be reheated to a more traditional supply-air temperature—55°F (13°C), for example—but not reheated all the way to neutral.

- **To avoid condensation when conditioned OA is delivered to the ceiling plenum**
  In some applications, the dedicated OA system delivers the conditioned outdoor air (CA) to the ceiling plenum, near the intake of each local HVAC terminal (see Figure 5, p. 4). The outdoor air mixes with recirculated air (RA) in the plenum before being drawn in through the intake of the local unit. In this configuration, the dedicated OA unit should reheat the dehumidified OA to a dry-bulb temperature that is above the expected dew-point temperature of the air within the ceiling plenum. If cold air is dumped into the ceiling plenum, it could cool surfaces (structural beams, electrical conduit, ceiling framework). At night, when the dedicated OA unit is off, wind or operating exhaust fans may cause humid outdoor air to leak into the plenum, which may lead to condensation on these cold surfaces.

Designing a Dedicated OA System

In most applications, in most climates, the dedicated OA unit is sized to dehumidify the outdoor air to remove the moisture, or latent load, from the entering outdoor air, and is often then dehumidified a little further. In this case, the resulting dew point of the conditioned air is drier than the space, dry enough that this quantity of outdoor air also removes most, or all, of the space latent loads (Figure 7).

Figure 7. Sizing the dedicated OA unit to offset space latent loads



In some cases, the local HVAC terminals may also help to dehumidify the space when the sensible-cooling load is high, yielding an indoor humidity that is drier than the maximum upper limit. As a rule of thumb, size the dedicated outdoor air unit so that it offsets both the ventilation load and the space latent loads at the peak outdoor-enthalpy condition.

Selecting the Dedicated OA Unit

The following steps establish the required airflow, dew point, and dry-bulb temperature for the conditioned air.

Step 1: Determine the entering-air condition. Three factors dictate the capacity required from the dedicated outdoor air unit: airflow, the enthalpy of the entering outdoor air, and the enthalpy of the conditioned air leaving the cooling coil. If the outdoor airflow is constant, then the basis of design is the condition resulting in the greatest difference in enthalpy across the cooling coil.

Indoor latent loads fluctuate with occupancy and processes, as well as with ambient conditions and wind through infiltration. These variables can make it difficult to discover when the greatest enthalpy difference occurs. However, if the latent loads within the space are relatively constant and infiltration is minimal, assume that the greatest enthalpy difference occurs at the highest outdoor air enthalpy.

In most climates, the peak latent ventilation load occurs at a lower dry-bulb temperature and higher dew point than the outdoor air condition that produces the peak sensible ventilation load. The *ASHRAE Handbook—Fundamentals* is a popular source for climatic data representing the outdoor design conditions for many locations. To aid the design of cooling and dehumidifying systems, the handbook includes:

- Peak dry-bulb and mean-coincident wet-bulb temperatures (sensible-design condition)
- Peak dew-point and mean-coincident dry-bulb temperatures (latent-design condition)
- Peak wet-bulb and mean-coincident dry-bulb temperatures (enthalpy-design condition)

The examples throughout this guide are based on "0.4 percent" data from the ASHRAE climatic data tables. This percentage indicates that the temperature is likely to equal or exceed the design value for 35 hours each year. Some design engineers choose to use more extreme conditions; others base their designs on the "1 percent" or "2 percent" values, which represent more hours.

Table 2 (p. 10) lists the 0.4 percent, cooling-design data for Jacksonville, Fla. Plotting these values on the psychrometric chart (Figure 8, p. 10) illustrates that the highest outdoor enthalpy exists at the peak wet-bulb condition. In this case, the enthalpy of the outdoor air is 9 percent higher than it is at the peak dry-bulb (sensible-cooling design) condition.

Note: Using the peak dry-bulb condition as the basis of design will undersize the dedicated outdoor air unit, making it unable to properly dehumidify the outdoor air at certain part-load conditions. Remember that the primary purpose of the dedicated outdoor air system is to properly control space humidity at all *load conditions.*

Step 2: Choose the maximum limit for space humidity. The leaving-air dew point is determined so that the space humidity level does not exceed some defined upper limit at worst-case conditions. Some design engineers might choose 50 percent relative humidity (RH) for the upper limit; others might choose to design the system to allow the humidity to rise a little higher (e.g., 60 percent RH) at worst-case conditions.

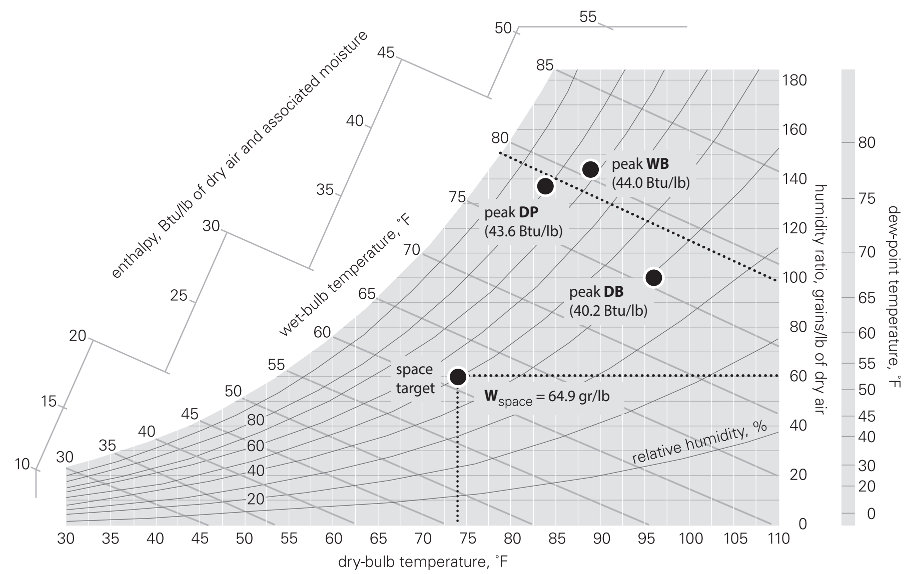
Note: Some types of local cooling equipment, such as chilled beams or radiant cooling panels, cannot handle any condensation. If this type of equipment is used, the outdoor air must be dehumidified to a dew point low enough to remove all of the space latent load plus some margin of safety to prevent condensation from forming on the local equipment. As an example, the upper humidity limit might be 55°F (13°C) dew point. This allows water at about 57°F (14°C) to be sent to the chilled beams or radiant panels without condensation.

In this example, combining the 75°F (23.9°C) setpoint for the space with a maximum relative humidity of 50 percent corresponds to a humidity ratio of 64.9 grains/lb (9.3 g/kg) or a dew point of approximately 55°F (13°C).

Table 2. Design weather conditions for cooling/dehumidifying in Jacksonville, Fla.[a]		
	Design condition	**Enthalpy**
Peak dry bulb, mean-coincident wet bulb	95.8°F (35.4°C) DB, 76.8°F (24.9°C) WB	40.2 Btu/lb (75.6 kJ/kg)
Peak dew point, mean-coincident dry bulb	78.7°F (25.9°C) DP, 83.7°F (28.7°C) DB	43.6 Btu/lb (83.5 kJ/kg)
Peak wet bulb, mean-coincident dry bulb	80.4°F (26.9°C) WB, 88.4°F (31.3°C) DB	44.0 Btu/lb (84.5 kJ/kg)

(a)Source: *2017 ASHRAE Handbook–Fundamentals,* Chapter 14 (0.4% condition)

Figure 8. Comparison of outdoor air enthalpies at 0.4% cooling-design conditions for Jacksonville, Fla.



Managing Building Moisture, Trane applications engineering manual SYS-AM-15, helps designers identify and quantify moisture sources. It also presents moisture-management techniques for the building envelope, occupied spaces, and mechanical equipment rooms.

Step 3: Determine the latent loads in the space. The dedicated outdoor air unit will offset the local latent loads in the space it serves, as well as the total ventilation load. Common sources of latent load include respiration from people, processes (such as cooking), and the infiltration of humid outdoor air through cracks and other openings in the building structure.

For this example, the dedicated outdoor air handler serves four classrooms of a school in Jacksonville, Fla. Table 3 (p. 11) lists the latent load for each space; in this case, the latent loads presumably remain constant whenever the building is occupied.

Step 4: Determine the total airflow that the dedicated outdoor air unit must deliver. If a centralized piece of equipment brings in outdoor air, and then delivers only outdoor air (not mixed with any recirculated air) to one or more ventilation zones, ASHRAE Standard 62.1 classifies this as a "100-percent outdoor air ventilation system." Accordingly, the system-level intake airflow (V_{ot}) delivered by the dedicated OA unit should be the sum of the calculated zone outdoor airflows (V_{oz}):

$$V_{ot} = \Sigma V_{oz}$$

Given the zone outdoor airflow requirements (V_{oz}) listed in Table 3, the dedicated OA unit in this example must deliver a total outdoor airflow of 1815 cfm (0.86 m^3/s).

Table 3. Design criteria for a DOAS serving four classrooms in Jacksonville, Fla. (example)

Space characteristics	Classroom 101	Classroom 102	Classroom 103	Classroom 104
Sensible load	29,750 Btu/hr (8.7 kW)	26,775 Btu/hr (7.8 kW)	26,927 Btu/hr (7.9 kW)	28,262 Btu/hr (8.3 kW)
Latent load	5,250 Btu/hr (1.5 kW)	5,465 Btu/hr (1.6 kW)	5,697 Btu/hr (1.7 kW)	5,250 Btu/hr (1.5 kW)
Sensible-heat ratio (SHR)	0.85	0.83	0.83	0.84
Required outdoor airflow	450 cfm (0.21 m^3/s)	450 cfm (0.21 m^3/s)	480 cfm (0.23 m^3/s)	435 cfm (0.20 m^3/s)
Humidity ratio of conditioned air, W_{ca}	48.0 grains/lb (6.92 g/kg)	47.3 grains/lb (6.76 g/kg)	47.7 grains/lb (6.84 g/kg)	47.4 grains/lb (6.80 g/kg)

Step 5: Determine which zone requires the driest conditioned outdoor air. Because the dedicated outdoor air unit will offset the latent loads in each space (as well as the total ventilation load), the conditioned outdoor air must be dry enough to enforce the maximum humidity limit in the worst-case space. Use the following equation to calculate the required conditioned-air humidity ratio, W_{ca}, for each space:

$$Q_L = 0.69 \times V_{oa} \times (W_{sp} - W_{ca})$$

$$(Q_L = 3.0 \times V_{oa} \times [W_{sp} - W_{ca}])$$

where,

Q_L = latent load in the space, Btu/hr (kW)
V_{oa}= conditioned outdoor airflow, cfm (m^3/s), which is supplied to the space by the dedicated outdoor air handler
W_{ca}= humidity ratio of the conditioned outdoor air, grains/lb (grams/kg)
W_{sp}= maximum limit for the humidity ratio in the space, grains/lb (grams/kg)

For example, to ensure that the humidity (W_{sp}) in Classroom 101 does not exceed the maximum limit of 64.9 grains/lb (9.3 g/kg), the humidity ratio of the conditioned outdoor air, W_{ca}, must be 48.0 grains/lb (6.92 g/kg).

Table 3 shows the results of this calculation for all four classrooms. Although the highest latent load exists in Classroom 103, the "critical space" is

In the Q_L equations at right, 0.69 and 3.0 are derived from the properties of air; they are *not* constants. At the "standard" air condition, which is 69°F (21°C) dry air at sea level, the product of density, the latent heat of water vapor, and a conversion factor for units—7,000 grains/lb (1,000 grams/kg) and 60 min/hr—equals 0.69 (3.0). A different air condition or elevation will result in a different value.

Step 5 (Classroom 101):

Q_L = 5,250 Btu/hr
= 0.69 x 450 cfm x (64.9 gr/lb - W_{ca})
$\therefore W_{ca}$ = 48.0 gr/lb

(Q_L = 1.5 kW)
(= 3.0 x 0.21 m^3/s x [9.3 g/kg - W_{ca}])
($\therefore W_{ca}$ = 6.92g/kg)

Classroom 102 because it requires the driest air (lowest humidity ratio, W_{ca}). Supplying the conditioned outdoor air at a humidity ratio of 47.3 gr/lb (6.76 g/kg) will offset the latent load in each classroom and assure that the humidity in Classroom 102 does not exceed the maximum limit; lower humidities will result in the other classrooms.

Step 6: Determine the required dew point for the conditioned outdoor air. With the help of a psychrometric chart (Figure 7), we find that a humidity ratio of 47.3 grains/lb (6.76 g/kg) is equivalent to a dew-point temperature of 46.7°F (8.2°C).

Step 7: Determine the supply-air dry-bulb temperature for the dedicated outdoor air handler. If the system design requires *neutral*-temperature conditioned air, then the air leaving the dedicated outdoor air unit must be reheated to the desired dry-bulb temperature. This is typically between 70°F and 75°F (21°C and 24°C).

If the system design is based on *cold* conditioned air rather than neutral-temperature air, then the dry-bulb temperature from the dedicated outdoor air unit depends on the supply-air dew point. In our example, assuming that saturated air leaves the cooling coil, then the leaving-air dry-bulb temperature may be delivered as cold as 47°F (8.3°C), or might be reheated to a more conventional air-delivery temperature, such as 55°F (12.8°C).

Note: For simplicity, our example does not include the effect of fan heat. A draw-through fan arrangement will increase the dry-bulb temperature of the conditioned outdoor air. The slightly warmer air offsets less of the sensible load in the space, which will affect the selection criteria for the local HVAC terminals.

Control of the Dedicated OA Unit

The most common approach to controlling the dedicated OA system is to turn it on when the building is expected to be occupied. The same time-of-day schedule that is used to start and stop the local HVAC terminal equipment is used to start and stop the dedicated OA system.

The fan in the dedicated OA unit is activated to bring in the required amount of outdoor air for ventilation, and cooling, dehumidification, or heating is modulated to maintain the discharge air at the desired conditions.

The operating mode for the dedicated OA unit is based on the current outdoor air conditions. Outdoor temperature and humidity sensors are used to calculate the outdoor air dew point, and compare it to the desired leaving-air conditions. This determines whether the unit operates in Dehumidification Mode, Sensible Cooling Mode, Sensible Heating Mode, or if conditions are sufficient for the unit to operate in Ventilation Only mode (Figure 9 and Table 4).

Figure 9. Dedicated OA unit control modes

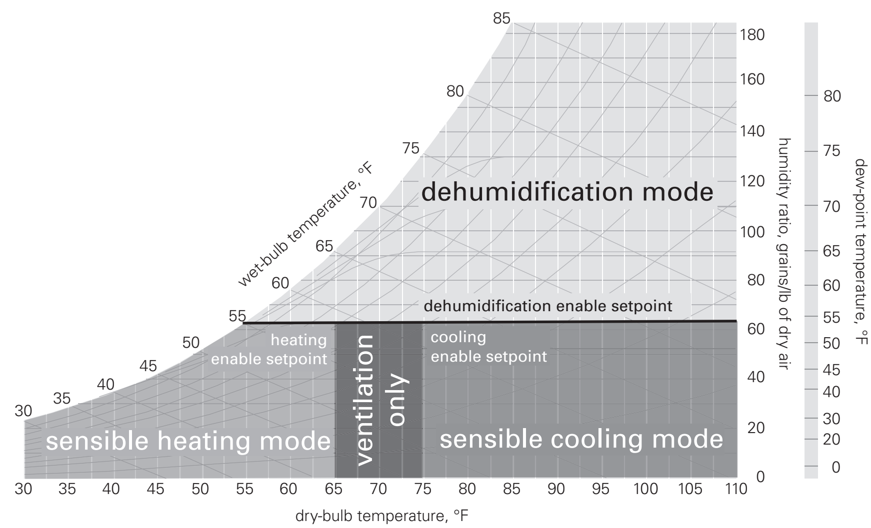
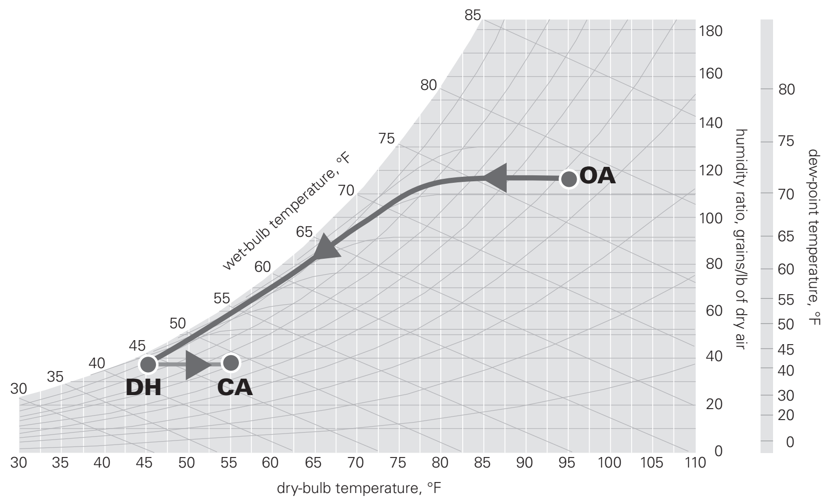


Table 4. Dedicated OA unit control modes	
Control mode	**Outdoor conditions**
Dehumidification	Outdoor Air Dew Point > Dehumidification Enable Setpoint
Sensible cooling	Outdoor Air Dew Point ≤ Dehumidification Enable Setpoint Outdoor Air Dry-Bulb Temperature > Cooling Enable Setpoint
Ventilation only	Outdoor Air Dew Point ≤ Dehumidification Enable Setpoint Heating Enable Setpoint ≤ Outdoor Air Dry-Bulb Temperature ≤ Cooling Enable Setpoint
Sensible heating	Outdoor Air Dew Point ≤ Dehumidification Enable Setpoint Outdoor Air Dry-Bulb Temperature < Heating Enable Setpoint

Dehumidification mode

If the outdoor air dew point is higher than the Dehumidification Enable Setpoint, the unit operates in the Dehumidification Mode (Figure 10). In this mode, compressor capacity is staged/modulated to dehumidify the outdoor air (OA) to the desired leaving-air dew point (DH). Depending on the application, this dehumidified outdoor air may then be reheated—using heat recovered from the DX refrigeration circuit (i.e., hot gas reheat)—to the desired leaving-air dry-bulb temperature (CA).

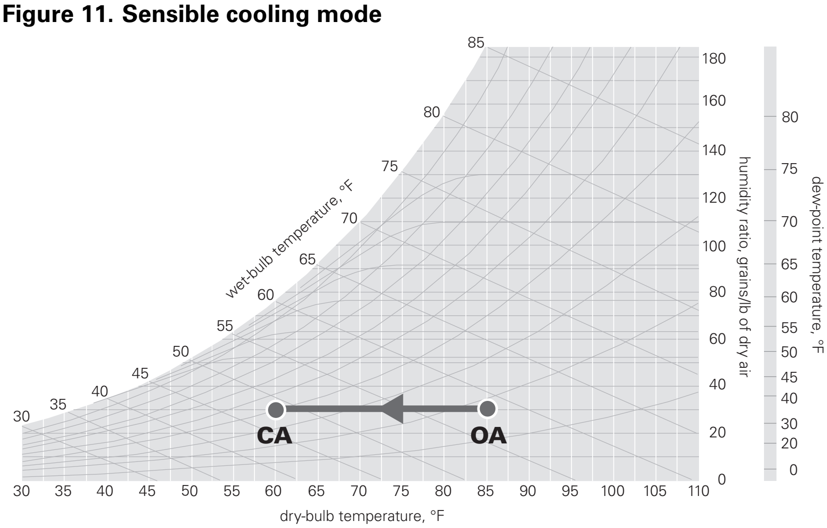
Figure 10. Dehumidification mode



Sensible cooling mode

If the outdoor air dew point is lower than, or equal to, the Dehumidification Enable Setpoint, and the outdoor air dry-bulb temperature is higher than the Cooling Enable Setpoint, the unit operates in the Sensible Cooling Mode (Figure 11). In this mode, compressor capacity is staged/modulated to cool the outdoor air (OA) to the desired leaving-air dry-bulb temperature (CA).

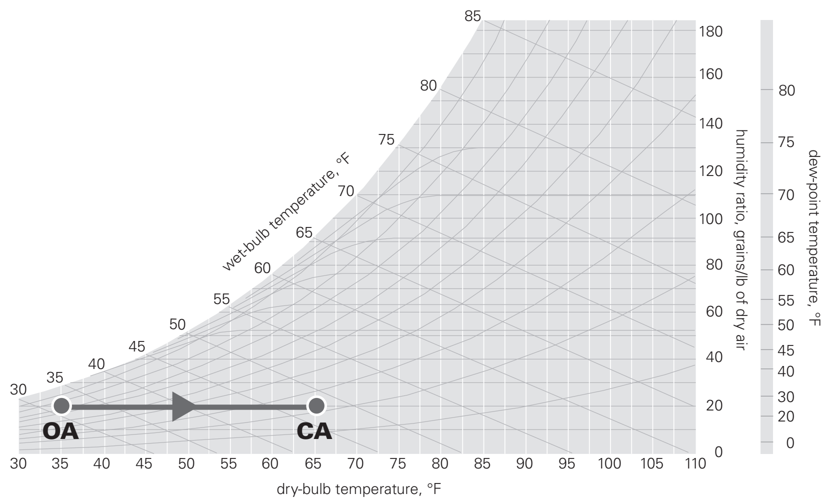
Figure 11. Sensible cooling mode



Sensible heating mode

If the outdoor air dew point is lower than, or equal to, the Dehumidification Enable Setpoint, and the outdoor air dry-bulb temperature is lower than the Heating Enable Setpoint, the unit operates in the Sensible Heating Mode (Figure 12). In this mode, heater capacity is staged/modulated to warm the outdoor air (OA) to the desired leaving-air dry-bulb temperature (CA).

Figure 12. Sensible heating mode



Ventilation only mode

If the outdoor air dew point is lower than, or equal to, the Dehumidification Enable Setpoint, and the outdoor air dry-bulb temperature is lower than the Cooling Enable Setpoint but warmer than the Heating Enable Setpoint, the unit operates in the Ventilation Only Mode. In this mode, the fan continues to operate, but both the compressors and heater are turned off.

References

American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE). 2012. "Dedicated Outdoor Air Systems" ASHRAE webcast. Atlanta, GA: ASHRAE. www.ashrae.org.

Trane. Murphy, J. and B. Bakkum. 2011. *Water-Source and Ground-Source Heat Pump Systems*, SYS-APM010-EN. La Crosse, WI: Trane.

______. Murphy, J. and B. Bradley. 2002. *Dehumidification in HVAC Systems,* SYS-APM004-EN. La Crosse, WI: Trane.

______. Murphy, J., R. Moffitt, P. Solberg, and J. Harshaw. 2011. "Dedicated Outdoor Air Equipment," APP-CMC043-EN (DVD). Trane Engineers Newsletter Live program. La Crosse, WI: Trane.

______. Stanke, D. and B. Bradley. 2001. "Dedicated Ventilation Systems," *Engineers Newsletter*, volume 30, number 3. La Crosse, WI: Trane.

______. Stanke, D., B. Bradway, A. Hallstrom, and N. Bailey. 1998. *Managing Building Moisture,* SYS-AM-15. La Crosse, WI: Trane.

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