Do All DOAS Configurations Provide the Same Benefits?

BY SHIHAN DENG, STUDENT MEMBER ASHRAE; JOSEPHINE LAU, PH.D., MEMBER ASHRAE; AND JAE-WEON JEONG, PH.D., MEMBER ASHRAE

Dedicated outdoor air systems supply 100% outdoor air (OA) (i.e., no recirculated air) determined by ventilation to one or more zones. The open literature[1–6] includes a clear definition[6] and benefits of DOAS as indicated by some leading industry professionals. However, system configurations and understanding of DOAS have been varying with time, and today there is a considerable diversity of DOAS readily found in our engineering community.

Personal communications were conducted between the authors and 21 experienced engineers from 10 major U.S. HVAC designing and consulting firms asking for their definitions on DOAS. Wide ranges of opinions were collected. The definition in this article attempts to be as inclusive as possible to reflect the various system configurations already applied under the name of DOAS. However, readers should be reminded that there are various pros and cons in each DOAS configuration. The benefits of DOAS will *not* be the same if different system configurations are applied.

DOAS, as presented by the authors of this article, is defined as: a system which uses separate equipment to condition all OA brought into a building for ventilation, delivered to each occupied space, either directly or in conjunction with local space or central (zoned) HVAC units serving those same spaces. The local or central HVAC units are used to maintain space temperature setpoint requirements.

Features/Benefits of DOAS

Based on a current literature review, the benefits of diverse DOAS designs, when compared to basic VAV system, may be one or more of the following:

- Easier to provide proper ventilation.[2,4,7–9]
- Decoupling sensible and latent cooling functions of air-handling systems.[2,8,10,11]
- Increased degree of freedom in the selection of local unit(s).[2,7,8]
- Reduction in energy use and demand for both the DOAS unit and local unit(s).[2,4,8]
- Enhanced indoor environmental quality (IEQ).[11,12]

Shihan Deng is a graduate student, and Josephine Lau, Ph.D., is assistant professor at Durham School of Architectural Engineering and Construction, University of Nebraska-Lincoln in Omaha, Neb. Jae-Weon Jeong, Ph.D., is an Associate Professor, Division of Architectural Engineering, Hanyang University, Seoul, South Korea.

Ventilation Benefit of DOAS

To realize the ventilation benefit of DOAS the OA must be supplied to each occupied space, or either directly, or in conjunction with, local units. The details of different configurations are further discussed in the following sections of this article.

One of the difficulties of achieving good ventilation performance with central HVAC systems (e.g., VAV systems) serving multiple zones is that the individual zone sensible loads do not necessary vary with their ventilation requirement. Therefore, increased system total ventilation intake airflows which are often required to ensure the proper ventilation for each zone at all operation conditions is in compliance with ASHRAE Standard 62.1.[8]

Another difficulty is over-ventilation of non-critical zones. In a multiple-zoned recirculating ventilation system, a single air handler supplies the mixture of OA and recirculated return air to more than one ventilation zone. Since the system delivers the same air mixture to each zone; proper ventilation to the critical zone (the zone requiring the highest OA fraction) will generally result in over-ventilation for other zones.[1]

When DOAS supplies required ventilation air to each zone, either directly or in conjunction with local unit(s), such system configurations overcome the previously listed problems. Allowing the DOAS to be sized separately ensures proper ventilation in each zone at design zone population.[8]

Humidity Control Benefit of DOAS

There is also humidity control benefits with a DOAS approach, albeit a secondary goal. The various humidity control benefits can only potentially be achieved if the described system configuration associated with each benefit is applied.

Since the 1989 edition of ASHRAE Standard 62 increased earlier mandated OA requirements, proper indoor humidity control is even harder to achieve with some types of HVAC systems, because bringing more OA into the building can sometimes result in raising indoor humidity levels in non-arid climates.[10] Also, this requirement brings more moisture into the system since OA accounts for a large portion of the overall latent load in most commercial buildings.[8] Rather than using one system to control both indoor humidity and temperature, DOAS uses two systems to control them separately.[11] The DOAS unit (the unit conditioning the ventilation air separately) can be sized to supply the exact amount of required ventilation air at a dew point low enough to also offset the indoor latent load, thus controlling the indoor relative humidity level without relying on local HVAC units. When humidity control becomes a goal of DOAS, a total-energy recovery device is generally required by ASHRAE Standard 90.1. In locations with cold winter, a pre-heat coil is suggested near the OA intake for frost prevention at the total-energy recovery.

Humidity control requires engineers to pay more attention to part-load operation. Popular VAV systems usually reduce the amount of total air delivered to the space during part-load conditions to achieve energy efficiency. However, when the space loads change, this can result in loss of indoor humidity control, even though indoor space temperatures remain at acceptable levels. DOAS overcomes this problem. During part-load conditions, with local unit(s) running under reduced capacity mode to fulfill the reduced sensible loads, the DOAS unit continues to supply air at a low enough dew point to maintain acceptable indoor humidity levels. This humidity control benefit is potentially available for almost all DOAS system configurations.

Other Benefits of DOAS

DOAS also may allow broader local unit selection options when the DOAS unit alone controls the indoor humidity and supplies OA to the occupied spaces, either directly or in conjunction with local HVAC unit(s). Also, if the DOAS unit controls all of the latent loads, the high efficiency sensible-only HVAC unit may be effectively used as the local HVAC unit. Using high efficiency local HVAC equipment can potentially increase the overall system energy efficiency.[2]

Because a DOAS approach generally results in conditioning less OA than with a VAV system approach, there is an increased potential to reduce energy usage associated with the ventilation air components, air conditioning, and fan operation. Under part-load conditions, local unit(s) may be able to switch off to save energy, when the DOAS delivers ventilation air directly to each zone or to the supply-side of local HVAC units.

There is a view among certain professionals that a key fundamental change has to be made to achieve better IEQ, which is to "decouple the traditional (VAV or CAV) system dual functions of maintaining thermal environment and providing needed ventilation."[12] From an indoor air pollutants transport perspective, the DOAS ventilation approach leads to predictable pressure differentials between adjoining spaces or zones, which minimizes transport of the potential airborne contaminants between zones. Furthermore, with DOAS applications, airborne contaminants that may be present in one zone are not immediately distributed throughout a facility by the HVAC systems.[13]

DOAS System Configurations

As mentioned above, different DOAS system configurations in current practices will lead to different benefits. In general, DOAS can be categorized into one of five system configurations:

1. Conditioned OA delivered directly to the occupied spaces;
2. Conditioned OA delivered to the supply-side of local HVAC units;
3. Conditioned OA delivered to the intakes of local HVAC units
4. Conditioned OA delivered to return air plenums, near local HVAC units; and
5. Conditioned OA delivered to the intakes of centralized, multiple-zone HVAC units.

The following sections address the fundamental differences between these configurations and associated special considerations.

Conditioned Air Dry-Bulb Temperature

There is more than one way to condition the air from a DOAS unit:

- The dry-bulb temperature (DBT) of the conditioned air (CA) is "neutral," which approximates room air dry-bulb temperature
- DBT of CA is "cold," i.e., significantly cooler than the room air dry-bulb temperature—generally about the same as the required CA DPT.[14,15]

The DOAS method of delivering "cold air" actually requires less overall cooling capacity than a "neutral-air" DOAS approach.[16] Although the installed cooling capacity of the DOAS OA unit is the same in either case (because it is sized for the dehumidification load), the latter "cold air" approach reduces the required cooling capacity of each local unit and eliminates the central heating required to reheating the CA to the neutral temperature. Consequently, the cold-air system consumes less overall building system-wide (aggregate) cooling energy for much of the year compared to a "neutral-air" DOAS system approach and it consumes less system-wide heating energy by virtue of its reduced need to reheat the conditioned OA.

However, while the dehumidified OA should be delivered cold whenever possible, as the space sensible cooling load decreases, this cold air may provide more sensible cooling than the space requires, resulting in overcooling. When the potential for overcooling exists, design engineers typically may consider implementing CA temperature reset to reduce the cooling capacity.

Alternatively, activating the corresponding local HVAC unit heating coil to prevent overcooling also may be a choice. If the overcooling problem occurs occasionally or in only a few spaces, the sensible cooling benefit of delivering the OA cold to all other spaces served by the DOAS may outweigh the heating energy needed to prevent these few spaces from overcooling.

At some load conditions, however, it might be more economical to reheat the cold OA centrally, using recovered energy. In this case, one should design the DOAS to deliver the air cold, and only reheat when needed in order to avoid individual space/zone overcooling.

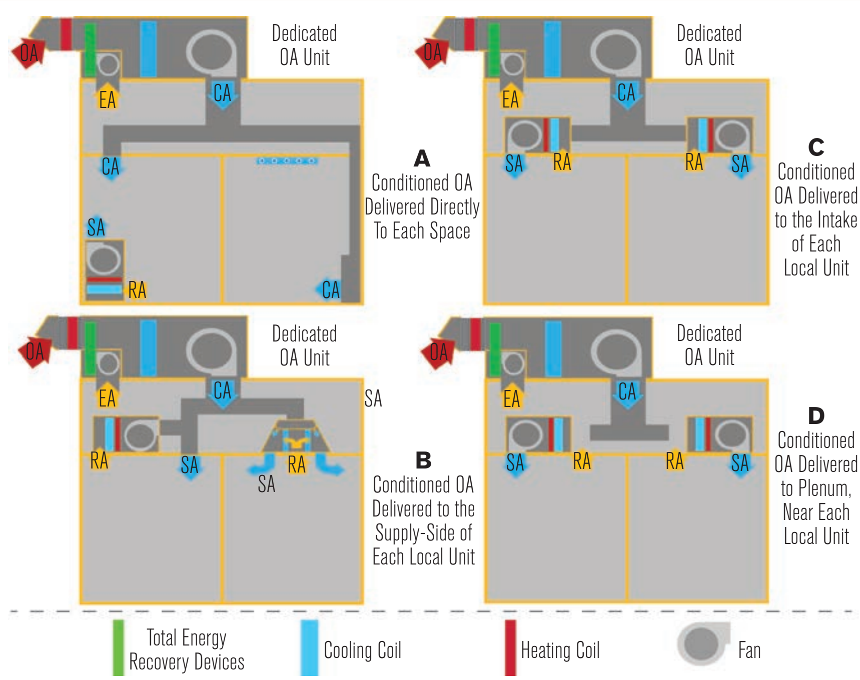

FIGURE 1: DOAS with total-energy recovery delivering OA.[17]

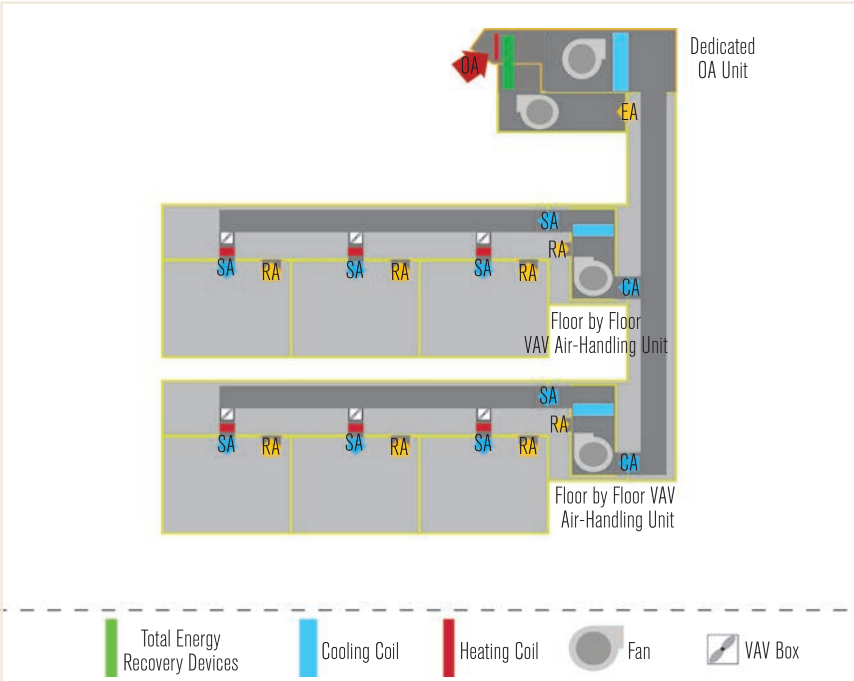

FIGURE 2: DOAS used with floor-by-floor VAV air-handling units[14] (re-created).

DOAS Supplies OA Directly to Occupied Space

In this system configuration, the conditioned OA is delivered by the DOAS directly to each occupied space. Meanwhile, the local unit(s) (such as fan coils, water-source heat pumps, packaged terminal air conditioners (PTACs), small packaged or split DX units, radiant chilled ceilings, passive chilled beams, and variable refrigerant flow (VRF) equipment) located in or near each space provides cooling and/or heating to maintain space temperature (*Figure 1a*).

This approach easily ensures the required OA flow reaches each zone, and affords the opportunity to cycle off the local fan, or reduce its speed, when cooling or heating from local unit(s) is no longer needed in a given zone. Since the OA is not distributed to the zone through the local unit, the local fans do not need to operate in order to deliver OA to the conditioned zone. Therefore, the DOAS can be activated during part-load periods without operating the local units.

When the conditioned OA is delivered at a cold temperature, rather than reheated to neutral, this configuration offers the opportunity to reduce the local equipment size (both airflow and cooling capacity) and hence also its capital and possibly operational energy costs. However, to prevent uncomfortable drafts when the conditioned OA is delivered at a cold temperature, one may need to use high performance diffusers that induce room air to mix with (and warm) the cold conditioned air before it reaches the occupied zone at the desired terminal velocity.

This configuration may require some additional ductwork and a separate diffuser for OA delivery to each occupied zone.

DOAS Supplies OA to the Supply-Side of Local HVAC Units

In this configuration, conditioned OA is ducted to the supply-side of each local unit(s) (*Figure 1b*), and is mixed with the local unit's supply air (SA) before being delivered to the zone/space. The local unit conditions only recirculated air.

Since OA flow is ducted to each unit, this configuration may ensure the required ventilation reaches each space, and the ventilation air is adequately distributed in the space through a common set of SA diffusers.

However, measurement and balancing of the ventilation system is more difficult with this approach than if the OA is delivered to the space. If the local fan cycles off, or varies its speed, the pressure in the supply duct decreases, potentially resulting in loss of proper-OA distribution.

It is suggested to install a pressure-independent terminal-box to directly control the OA flow into the space under different static pressure in the SA duct. This terminal approach can also be used to incorporate some method of demand-controlled ventilation (DCV).

When the OA is delivered at a cold temperature, rather than reheated to neutral, this configuration may also permit the downsizing of the local units (both airflow and cooling capacity).

DOAS Supplies OA to the Intake of Local HVAC Units

In this configuration, the DOAS may deliver the conditioned OA to the intakes of local single-zone HVAC equipment (such as fan coils, water-source heat pumps, small packaged or split DX units, variable refrigerant flow (VRF), small packaged rooftop units, or single-zone air handlers), where it mixes with recirculated air from the zone (*Figure 1c*). The local unit then conditions this mixture and delivers it to the zone through a single duct system and diffusers. This configuration ensures the required OA flow reaches each zone; since it is ducted directly to each unit, and often avoids some of the cost and space required to otherwise install additional space delivery ductwork and separate diffusers.

The OA is distributed by the local fan through a common set of diffusers ensuring that it is adequately dispersed throughout the zone. However, local HVAC equipment employing fans must operate continuously whenever ventilation is needed during occupied modes; otherwise, if the local HVAC equipment fan cycles on and off, or varies its speed, ventilation is compromised, since the local equipment fans are responsible for delivering ventilation air to the occupied zone/space.

In addition, when the conditioned OA is delivered to the intake of the local unit at a cold temperature, it results in cooler air entering the cooling coil of the local unit which derates its capacity. One may need less cooling capacity from the terminal device, which permits downsizing (cooling capacity, but not airflow). However, this may cause an equipment selection challenge for some types of local units.

DOAS Supplies OA to Plenum, Near Local HVAC Units

This configuration delivers conditioned OA to an open ceiling plenum, near the intake of each local unit (*Figure 1d*). The OA mixes with recirculated air in the plenum before being drawn into the intake of the local unit. This approach has been used when local units are installed in the ceiling plenum, such as water-source heat pumps, fan-coils, or variable refrigerant flow (VRF) terminals.

In this configuration, one may save the cost and space needed to install additional ductwork, separate diffusers, or mixing plenums on the local units. However, it is difficult to ensure the required amount of OA reaches each zone, since the ventilation airflow is not ducted directly. The ASHRAE Standard 62.1 *User's Manual* clarifies that the OA duct needs to deliver air near the intake of each local unit and include some means of balancing to ensure the right amount of ventilation air reaches each unit.

When cold conditioned OA is delivered to a plenum, it cannot be at a temperature below the prevailing dew point temperature encountered. In most cases, the ventilation air should be reheated some amount to avoid condensation on surfaces within the plenum.

DOAS Supplies OA to Centralized, Multiple-Zone HVAC Units

This approach uses DOAS to dehumidify all of the OA to a dew-point condition that is drier than the zones. This dehumidified OA is then ducted to the intake of one or more air-handling units. In *Figure 2* (Page 55), the DOAS delivers the conditioned OA (via ductwork) to floor-by-floor VAV air-handling units. Since OA is not directly delivered to each room and is mixed with the recirculating air, the multiple zone equations contained in ASHRAE Standard 62.1 should be used to determine the OA required at each air handler and to properly determine the total OA flow at the DOAS unit. However, this DOAS configuration may cause over-ventilation to satisfy the needs for the critical spaces.

Conclusions

In summary, there are many potential benefits in applying DOAS such as it is easier to ensure proper ventilation; decoupling latent and sensible loads control; providing energy use and demand reduction and better IEQ. Some benefits of DOAS will only be realized when particular and proper system configurations are chosen.[6] The DOAS system configuration of delivering conditioned OA directly to the individual space is highly recommended.[15,16,18] Engineers and researchers are still developing and exploring new DOAS system configurations. With the benefits presented in this article, HVAC design engineers are encouraged to pursue properly configured DOAS in their HVAC system designs.

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