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Variable Volume DOAS Fan-Powered Terminal Unit

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ASHRAE, LEED, and local codes advocate, if not require, that energy use in buildings be reduced. Of course, before there can be any marked reductions, there must first be a point of reference by which to run a comparison. As outlined in ASHRAE/IES Standard 90.1 for air-distribution systems in large buildings, a traditional overhead system that employs well-mixed VAV terminal units and ceiling diffusers is the baseline. For smaller or more specialized applications, it could be something entirely different. However, once established the challenge becomes how to best capture the efficiencies while satisfying a number of other requirements.

DOAS as a Solution

Engineers, owners, and architects have begun to consider alternate air-distribution systems (touted as environment-friendly or green), fearing the obstacles to achieving efficiencies using the baseline (overhead) system. These include underfloor air distribution (UFAD), displacement ventilation, variable refrigerant flow, water source heat pumps and chilled beams. In general, these technologies have been popular solutions to address the need for reducing energy consumption, but they do not always take into account the requirements for increased quantities of outdoor air. This is why using a dedicated outdoor air system (DOAS) has become more popular in recent years. It integrates well with a number of different devices, and it can help meet the requirements for both ventilation and humidity, while keeping the quantity of outdoor air to a minimum (which helps control building energy consumption).

Today's Building Facts, Standards and Requirements

Of course, when considering any system, much less a DOAS integration, it is important to understand some key facts about today's buildings and commonly referenced standards and building codes.

- For any system using overhead heating, one must comply with the requirements for overhead heating in Table 6.2, of ASHRAE Standard 62.1, where it outlines the requirements for additional ventilation air should the heated air temperature be more than 15°F (8.3°C) above the average room temperature.
- ASHRAE research has shown that many office spaces tend to operate at far lower loads than designed (6 W/ft^2 [0.6 W/m^2]), which equates to about 1 cfm/ft^2(0.1 W/m^2)(a common ratio found with overhead systems that use 55°F [13°C] supply air).
- Quite often, interior zone loads are so low that the ventilation rate alone can handle the comfort conditioning of the space, which makes these areas already at 100% outdoor air.
- Minimum ventilation requirements will vary throughout a space and are likely change over time. They can go from zero for areas that are rarely occupied (e.g., mechanical room) to a space that may have a high occupancy (e.g., classroom).
- Ventilation rates are dynamic and need to be managed, if not also measured. In fact, it is very possible that in the future, there will be standards that will require the ventilation rate to be measured. There may even be building rating system credits offered for doing so.
- Modern buildings designed with alternative air-distribution systems that use traditional design practices can lead to situations where energy-saving features of

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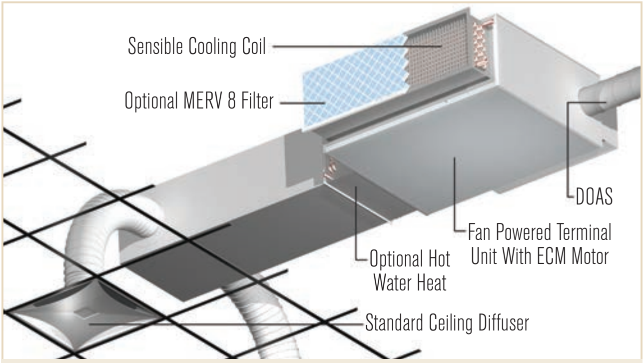

FIGURE 1 Chilled fan powered terminal unit.

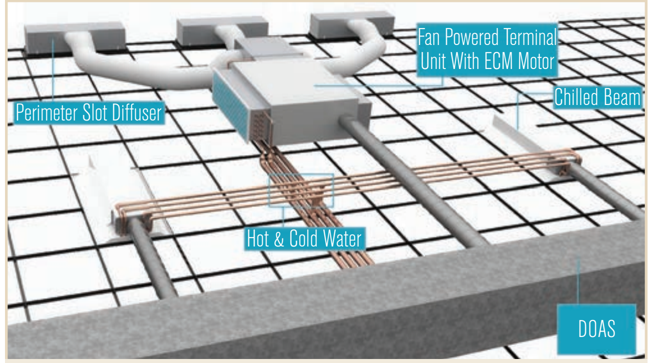

FIGURE 2 DOAS terminal unit used in perimeter application: Chilled beams placed within the interior and linear slot diffusers placed on the perimeter.

these new systems cannot be realized nor operated in economizer mode.

DOAS Unit: What It Is

Having already been used in a number of projects, including the Pentagon, a variant of the series fan-powered terminal unit has been able to effectively provide control of dynamic ventilation requirements while offering additional energy savings. The modified unit is the same as the regular series fan-powered terminal unit, with the exception of a cooling coil added to the induction opening (to handle sensible as opposed to latent loads). Once installed, the water temperature just needs to be controlled so that it stays above dew point. In fact, the mechanics of the DOAS fan-powered terminal unit are not that different from induction terminal units under windows or chilled beams in the ceiling.

When the unit is specified with an electrically commutated motor (ECM) and a VAV damper (usually smaller than with a standard design) that is connected to DOAS ductwork system, it can offer a number of additional control strategies that are not available with other types of air delivery systems. Such strategies can be employed to produce the best combination of airflows and discharge temperatures to meet both comfort and aesthetic requirements. While an ECM typically requires an analog signal for setting the airflow rate, there are many low cost, direct digital control (DDC) suppliers that can provide combinations of digital and analog outputs that can be easily configured.

Some may see similarities between the DOAS terminal unit and a fan coil, but the variable DOAS damper control and ECM variable fan operation makes it quite different. Another differentiating feature is how the units are rated. Items such as octave band sound power, motor amp draw, and other AHRI ratings are not yet required for fan coils. As with other terminal units, this certified data provides engineers with the assurance that their systems will perform as designed.

DOAS Unit Benefits

Many other benefits of a DOAS terminal unit include:

- Delivering air by traditional means to several spaces from a single cold water, power, and DOAS connection simplifies installation and allows for greater flexibility than alternative systems that require piping to each zone.
- By using standard, proven, and well-documented ceiling air outlets, ADPI (occupant comfort) can be predicted and compliance with ASHRAE Standard 55 (Thermal Comfort) can be proven. In an earlier article, "High Performance Air Distribution Systems," March 2014, we discussed how a properly designed array of air outlets can manage both sensible and latent loads at far lower room loads and corresponding air supply rates.
- The large sensible cooling coil (required to both maximize the output of a coil with 55°F to 60°F [13°C to 16°C] water and to minimize pressure drop through the coil), allows the addition of a MERV 8 filter for use during construction. While there is a LEED point for installing a filter during construction, it is not required for later building operations; most designs recommend its removal after construction is complete.
- There are opportunities to deliver conditioned air to spaces at a lower installed cost compared to other technologies that are labeled as "energy efficient." (While dependent on many different factors significant savings

can be achieved with the DOAS terminal unit more often than not.)

- Significant energy savings can be realized when the ECM speed is adjusted as needed to respond to the given room load.
- Installing contractors and building maintenance personnel will be dealing with familiar technology.
- The DOAS terminal unit cabinet includes insulation, which allows it to be operated with exceptionally cold (and consequently dry) primary air delivered from the DOAS air handler.
- Hot water coils, or staged or proportional electric coils can be included to satisfy (perimeter) heating needs.
- The DOAS terminal unit has no need for a drain pan, as it only handles sensible cooling, which does not produce any condensate.

DOAS Unit Considerations

As with any technology, there are a host of details that must be considered. These include:

- The sensible cooling coils require a network of water pipes (hot and cold) routed throughout the ceiling cavity of the building; however, there is considerably less piping used than with a chilled beam system.
- If the DOAS air handler uses chilled water for dehumidification, the building will need two chilled water supply temperatures: one cold enough to dehumidify at the DOAS air handler and another to provide water above dew point to the fan-powered terminal units.
- Some engineers in humid climates may require that the units be provided with a drain pan or condensate pan on these type of units because they are worried that the building operator will set the water temperature too cold in relation to the indoor dew point, which may be higher than planned at certain times. (i.e., at startup after a weekend)
- In a tall building, stack effect may create an uncontrollable and unpredictable infiltration of outside air into the lower floors. Unfortunately, it is difficult to calculate how much dehumidification would be required at the design stage. Instead, engineers may elect to use ECM fan coils with colder water, but that, too, would require two cold water loops.

DOAS Unit Efficiencies

Using water as the means by which to cool a building is not only efficient, but it is a basic feature of both under-window and chilled beam induction systems. Using a DOAS terminal unit with an ECM, can achieve significant energy savings by removing the need for a central fan to power the induced plenum (or room) air. Instead, a much smaller, energy-efficient DOAS air handler is used to only provide the required ventilation air to the space. The minimum pressure requirement for a series fan-powered terminal is negligible, as the cabinet has negative pressure and will essentially draw air out of a supply duct. To maximize the savings potential of the DOAS terminal unit, the variable volume feature of the ECM must be used, where the fan is running at the lowest speeds as often as possible.

An ECM in a series fan-powered terminal unit can be (and typically is) programmed to be pressure independent. This means that the computer program in the motor compares the desired airflow signal provided by the DDC system to the rpm, torque, and stored fan curve to ensure that the fan delivers precisely the required airflow rate. Most manufacturers will guarantee that it will be within 5% of the required flow over a broad range of performance.

The result is that the control system can perform several very important operations.

- The fan must always deliver more air than is provided by the primary air (ventilation air). A typical VAV inlet is pressure dependent to within 5%, and is controlled by the DDC system. Since the system is now controlling both, this requirement can now be easily met over a broad airflow range.
- Operating the fan at very low airflow rates provides huge energy savings potential. Since we now know that the air outlets can provide an acceptable environment at flow rates as low as 0.2 cfm/ft^2 (1 L/s·m^2) (with a proper diffuser selection and arrangement), the DOAS terminal unit can ramp down to these low airflow rates when the sensed load is low. At the same time, minimum ventilation rates are ensured and verifiable by way of the DOAS terminal unit air valve.
- Subcooling, which can happen when ventilation rates exceed the load, can be easily controlled by simply increasing the fan cfm to induce warm plenum air and offset the cool and dry DOAS air. This strategy would also apply to humidity control without reheat on a zone by zone basis.
- The DOAS terminal unit is ideally suited to handle temporary high solar loads that typically occur in early morning or late afternoon when the sun shines furthest

into a building. During these times, sensible cooling alone may not be able to fully support the load, but it can be handled if the system is set to reduce the primary airflow to the interior DOAS terminal units and increase the primary air to the perimeter units (which have a slightly oversized primary inlet). The interior units will still see this DOAS air, as the perimeter ventilation air will indirectly feed back into the interior zones.

- Perhaps most importantly, the combination of variable fan and controlled DOAS airflow allows for smart economizer operation. The sensible cooling coil can take care of sensible loads without the need for the DOAS air handler to do any dehumidification, provided that the outdoor air is dry enough. With zone heating coils, cold, dry outdoor air can be introduced and heated as necessary and can greatly expand the range of acceptable economizer conditions across many climates. Furthermore, as stated in several recent ASHRAE Journal articles, maximizing the delivery of ventilation air to spaces has proven advantages including, decreasing absenteeism, increasing productivity, and even enhancing learning abilities.

Verification of Building Energy Consumption

Furthermore, a research project, sponsored by AHRI and ASHRAE (RP 1292), performed at Texas A&M University, has been completed recently. The goal was to gather performance parameters for use in predicting a building's total energy consumption. In it, they took series and parallel fan-powered terminal units as well as PSC and ECMs and looked at how they affected the total system energy consumption. What became obvious was that today's energy calculation programs do a poor job of characterizing the energy consumption of buildings that use fan-powered terminal units. As a result, these two organizations have come together to institute an additional program by which to incorporate these results into Energy Plus and other available programs (AHRI Project 8012). This will help to demonstrate, with greater understanding, the advantages inherent to these types of terminal units, including the DOAS variant.

DOAS Unit & Other Technologies

While the DOAS terminal unit can be used as the sole solution for comfort conditioning, it also can be used to supplement other systems, such as chilled beams. In fact, chilled beams are natural partners with the DOAS terminal unit in that they both would use the same entering water temperature for the cooling coils and the same ventilation air (the air, however, would not be as cold as in a pure DOAS terminal unit application). In colder climates, perimeter zones may present a challenge to chilled beams designs where there are high perimeter heat demands, but they can be easily managed with a fan-powered terminal unit.

Other innovative strategies being considered include both DV and UFAD systems. The challenge for these particular applications is providing 63°F (17°C) air with a much lower dew point. Fortunately, the DOAS terminal unit can easily accomplish this on a zone-by-zone basis.

Summary

Today's design engineers face a series of complex decisions in an effort to reduce energy consumption and maintain comfort, all while meeting a variety of codes and standards. One option that seems to satisfy all these requirements is a DOAS fan-powered terminal unit. Its combination of a variable speed ECM fan, large sensible cooling coil, and small DOAS primary air valve allows for the widest possible range of operational strategies that both minimize energy and maximize ventilation control. Used either alone in a traditional overhead application or integrated with newer system technologies, it is sure to be a solid option for engineers seeking sustainable air-distribution solutions. ■