Using Dedicated Outdoor Air Systems

Demand Controlled Ventilation

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C arbon dioxide-based demand controlled ventilation (DCV) for VAV systems is intended to resolve the traditional conflict between operating cost and verifiably maintaining ventilation for acceptable indoor air quality as required in ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*. If properly applied, DCV can be expected to:

   • Reduce energy operating costs during off-design occupancy, compared to all-air VAV systems operating with a fixed design minimum OA. (Savings are achieved by reducing overventilation of partially occupied zones.)

   • Accommodate infiltration, exfiltration, local exhaust, and inter-zonal transfer.

   • Maintain the desired ventilation rate per person compared to most all-air VAV approaches designed to accommodate variable occupancy.

Mumma

It has been shown[1] that, for multiple space systems, a single CO_2 sensor in the common return causes critical spaces to be underventilated, in some cases by up to 90% (i.e., only 2 cfm [0.9 L/s] per person instead of the required 20 cfm [9.4 L/s] per person). Consequently, sensors must be located in enough zones to detect the critical spaces. Zones with short circuit paths between the supply and return air can create CO_2 measurement problems, which can lead to a failure to meet Standard 62.

With properly operating DCV systems, the required minimum quantity of OA decreases roughly in proportion to the total building occupancy reduction. With a uniform percent occupancy reduction in every zone, the percent OA reduction is nearly the same as the total building occupancy reduction. And with non-uniform percent occupancy reduction in the building, the percent OA reduction is less than the total building occupancy reduction.

In any event, the literature[2] warns that when DCV is used,
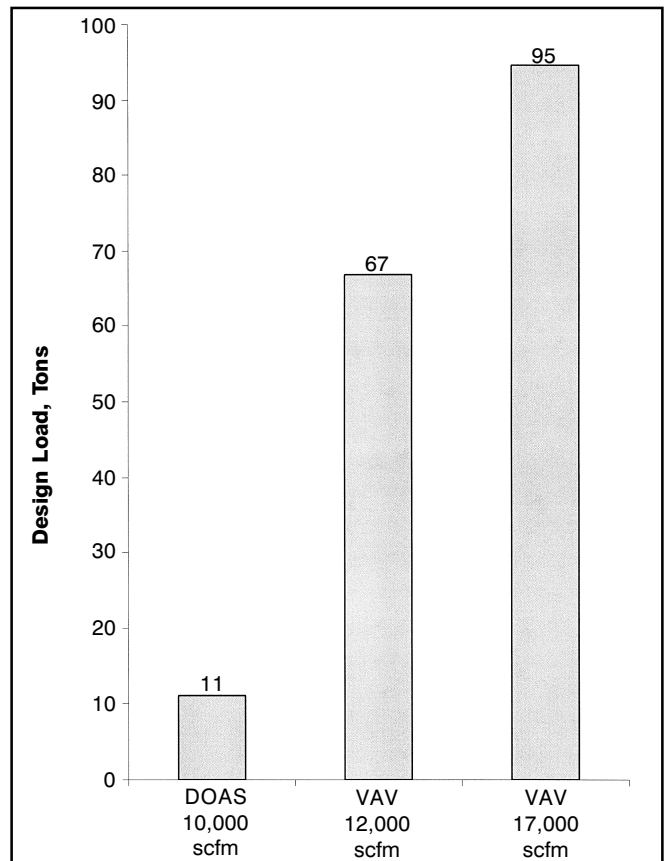
**Figure 1: OA load on the chiller, Atlanta.**

ventilation rates should not be reduced below 20% to 50% of design. Maintaining this minimum rate supplies sufficient ventilation air to dilute building contaminant sources, even at low occupancy levels.

Dedicated OA Systems

   The dedicated outdoor air systems (DOAS) discussed here supply the design minimum outdoor air directly into every zone of the building while working with a parallel comfort conditioning system.[3] The OA generally is preconditioned[4] to some extent, depending on:

   • the parallel system used to meet zone loads;

   • how the OA is introduced into the zone; and

Application Issues
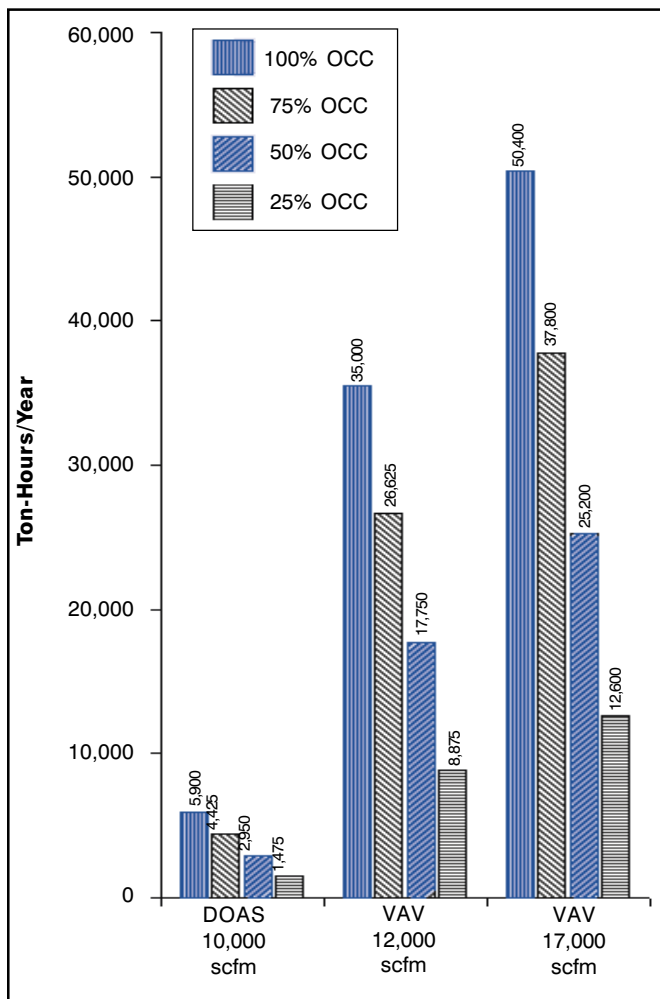
Figure 2: Annual ton-hours on the chiller for Atlanta with DCV.

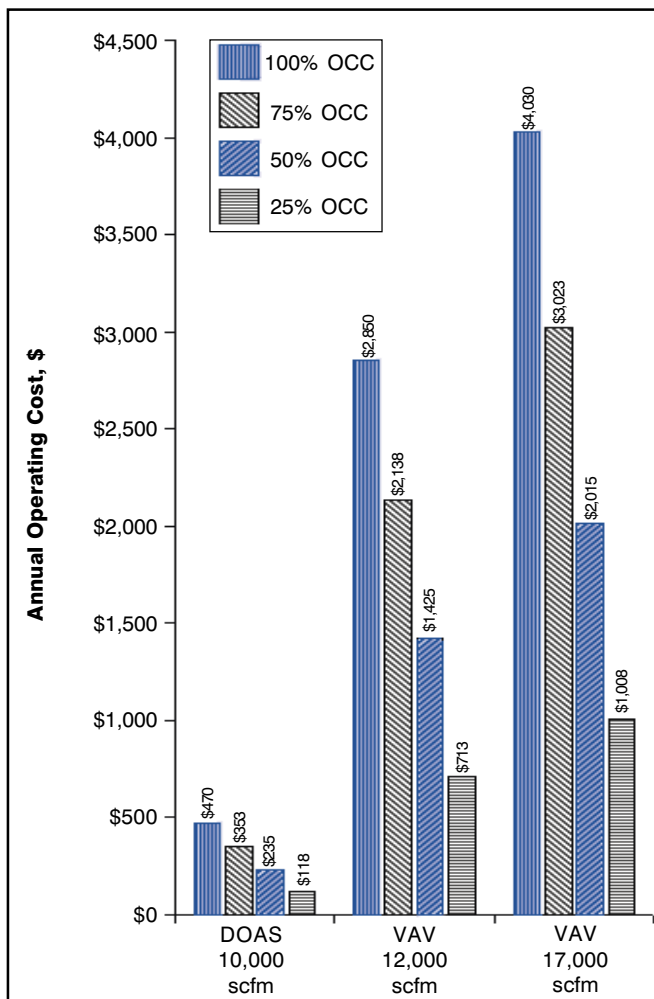Figure 3: Operating costs to condition OA, based on 0.8 kW/ton and $0.10/kWh.

• the extent of energy recovery used.

For buildings with design DOAS flow rates more than 7,000 cfm (3300 L/s), ANSI/ASHRAE/IESNA Standard 90.1-1999, *Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings,* requires total energy recovery. For much of the United States, the design wet-bulb temperatures are sufficiently high that Standard 90.1-1999 requires an enthalpy wheel. An enthalpy wheel, with an effectiveness of 80%, is capable of preconditioning the OA to within 20% of the zone(s) return air conditions (dry bulb and humidity ratio). This yields a large reduction in the outdoor air latent and sensible cooling, or heating and humidification loads.

The result of total energy recovery is that the OA cooling and dehumidification loads are reduced by 80%. Heating of OA is nearly eliminated as is the need for winter humidification.

Energy Consumption

Atlanta weather data is presented for evaluating DCV's impact on annual energy consumption. The example assumes

that the uncorrected OA at design occupancy is 10,000 scfm (4700 L/s) and the space conditions are maintained at 75°F (24°C) dry-bulb temperature and 50% RH. Typical Meteorological Year (TMY) data were used, assuming that the building would be occupied 6 days per week, from 7 a.m. to 7 p.m.

When the multiple spaces equation of Standard 62 is applied, the uncorrected OA increases by 20% to 70%. Because of this, a fully occupied building served by an all-air VAV system would need to supply the corrected OA flow rate of between 12,000 to 17,000 scfm (5700 – 8000 L/s), while a DOAS would only need to supply the uncorrected 10,000 scfm (4700 L/s) of OA. The design OA load on the chiller for the DOAS and for a VAV system with the lower and upper OA flow rates is presented in *Figure 1*.

Because Standard 90.1-1999 requires the DOAS to use total energy recovery and needs to condition only the uncorrected OA flow, the peak OA load on the chiller is only 11 tons (39 kW). Since the DCV's intent is to reduce energy consumption, it is the author's experience that it is not used with total energy recovery equipment. Therefore, the design impacts of the VAV system's corrected OA flow rates of 12,000

and 17,000 scfm (5700 and 8000 L/s) on chiller size are reflected in the 67 and 95 ton (236 and 334 kW) OA loads.

The annual ton-hours (TH) to condition OA for the DOAS and the VAV systems are presented in *Figure 2.* The 100% occupancy for the two VAV cases is what would be required if the systems did not use DCV or the building was always at design occupancy. The partial occupancy TH estimates are based upon the assumption that the required OA flow is proportional to occupancy. The DCV partial occupancy performance has also been applied to a DOAS.

Based upon the previous TH data, the annual energy cost to condition OA for the various situations are presented in *Figure 3,* assuming a chiller kW/ton of 0.8 and electricity rate of $0.10/kWh.

Results

The 8,875 and 12,600 TH (31 210 and 44 310 kWh) of cooling required to condition the OA for the two VAV-corrected OA flow rates, even when the rate was reduced to 25% of the design requirement by the use of DCV, exceeds the 5,900 TH (20 750 kWh) of cooling required for the DOAS without DCV. When these differences are seen in financial terms *(Figure 3),* a building that averages only 50% occupancy, costs about $1,000 to $1,500 more to operate than a DOAS without DCV. Annual savings that the DOAS generates with DCV when the building is 50% occupied is only about $235, making it hard to justify the added complexity and first cost. Adding DCV to DOAS would require that its constant volume supply controls be upgraded to accurately control the variable volume flow associated with DCV.

> It is the author's opinion that the DOAS approach provides superior energy performance, less complexity, and reduced first and operating costs, while improving zones' IAQ. DCV is a valuable new ventilation control for all-air VAV single supply air duct systems, but it does not offer the benefits of DOAS. Integrating DCV with DOAS offers minimal operating cost savings, and increased system complexity and first cost.

Conclusions

On the basis of the energy consumed and the operating cost benefits of the DOAS, it is an excellent way to meet the ventilation requirements of Standard 62. Other factors that favor selecting a DOAS over any system using DCV are:

- The chiller plant demand is reduced.

- A first-cost savings for the chiller offsets the cost of the enthalpy wheel, and reduces kW demand charges.

- The constant OA supply of the DOAS without DCV maintains the design OA cfm/person without energy penalty, improving overall sense of health and comfort in occupied zones.

- Building-related contaminants can never accumulate to unacceptable levels at low occupancies.

- The OA can be preconditioned to meet all OA sensible and latent loads as well as zone latent loads. When the zone sensible and latent loads are decoupled, potential microbial problems in the building are reduced or eliminated.

- A Lawrence Berkeley National Laboratory report estimates that by avoiding microbial problems, businesses could save as much as $208 billion/year.[5]

- By using high induction diffusers with DOAS, opportunities for short circuit paths between the supply and return are nearly eliminated.

- Finally, since the DOAS is a 100% OA system, local infiltration, exhaust, and interzonal transfer do not impact IAQ as they do in VAV systems, with or without DCV.

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