Demand control ventilation

Buildings require a certain amount of ventilation, or outside air (OA), in order to ensure good indoor air quality. Typically the required amount of ventilation is calculated using the building's maximum occupancy. Buildings, however, are rarely at full capacity, which means more outside air is supplied than necessary, resulting in unnecessary energy spent heating and cooling that air. Demand-control ventilation (DCV) reduces OA based on the number of people in the building. Building energy codes now require DCV in some spaces. But there are several cost effective ways to use this energy conservation measure beyond those required by code.

The two primary methods for controlling OA use either carbon dioxide sensors or occupancy sensors. A carbon dioxide sensor modulates OA proportionally to the number of people in the space and works best in large spaces with variable occupancy. An occupancy sensor works better for smaller spaces as it either toggles ventilation completely on or off based on occupancy. Typically using a combination of these two approaches within the building will save the most energy while maintaining good indoor air quality. For most systems, DCV saves only heating and cooling energy. However if ventilation air is supplied by a dedicated outside air system, DCV will also save fan energy. Fan energy is cubically proportional to fan speed, so reducing fan speed can save significant energy. In a recent study of six buildings, the average annual energy savings from implementing DCV was $0.59 per CFM of design OA.

DEMAND CONTROL VENTILATION AT 749 UNIVERSITY ROW

The building at 749 University Row is a highly energy efficient, multi-tenant office building constructed in Madison, Wisconsin in 2013. This building is served by a dedicated outside air system (DOAS) to meet ventilation requirements. The DOAS system uses a timeclock to supply OA from 6 A.M. to 6 P.M. on weekdays. The DOAS serves the ventilation needs of all the tenants in the building. To allow individual tenants to use DCV in their space, the building owner had a variable frequency drive (VFD) installed on the DOAS. In essence, this transitioned the DOAS from a constant volume to a variable volume system.

Even without any DCV controls, the VFD on the DOAS saves energy. Because the DOAS system was selected before all the tenant spaces were designed, it was oversized to ensure that each tenant would have adequate ventilation. The VFD allowed the balancing contractors to reduce the upper limit for OA so it matched the final OA design for all the tenant spaces, instead of the oversized system's OA rate. The balancing contractor adjusted the OA rate with each tenant move in, a process that was staggered over a year before the final tenant occupied their space, so OA was only supplied to occupied tenant spaces.

In order to tune OA rates even further, building tenants could install controls to allow OA to modulate with occupancy. The tenants were not financially responsible

Figure 1: 749 University Row's dedicated outdoor air system

COST OF DEMAND CONTROL VENTILATION

EQUIPMENT	COST
Variable flow on outdoor air unit	$3,000
Carbon dioxide sensor, installed	$700
Incremental cost of wireless occupancy sensor controlling both lights and ventilation	$100
Incremental cost of occupancy sensor controlling both lights and ventilation	<$50 incremental
Typical cost to implement DCV	$1–$3 per CFM design OA
Typical payback	4-5 years

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Figure 2: Carbon dioxide sensor

Figure 3: Occupancy sensor

for DOAS energy consumption, so there was no economic incentive to install controls. Despite this, several tenants including Seventhwave, UW Health and Potter Lawson included controls in their spaces to save energy and/or receive additional LEED points.

Seventhwave installed both occupancy sensors and carbon dioxide sensors in its three largest conference rooms. This control combination shuts off ventilation to the conference rooms when the spaces are empty, and then ramps it up based on occupancy. The occupancy sensors selected control the lights in the conference rooms as well as the ventilation. Most occupancy sensors only have one contact and therefore can only control one output, so a slightly more expensive occupancy sensor with two contacts was used for this application. It is very cost effective to control ventilation if the system is a variable speed system and a room already has an occupancy sensor to control lighting.

The typical monitored OA flow reduction at 749 University Row as a result of DCV can be seen in Figure 4. The OA rarely exceeds 7,000 CFM, although the system has the capacity to reach 8,800 CFM. The highlighted area between the design OA and the monitored OA is the OA reduction, which correlates to cooling, heating, and fan energy savings. The energy savings are a combination of reducing the upper limit for OA to meet final design requirements and modulating the OA with occupancy. Despite the sophisticated controls, the total energy savings for this system are below average. Savings are limited because both DCV and energy recovery ventilation (ERV) were implemented in this building. The ERV has already significantly reduced the amount of energy required to condition the outside air, so there is less energy remaining to be saved by DCV. If a design team had to choose between DCV and ERV and couldn't spend the resources for an energy analysis, a good rule of thumb is to choose DCV if the building is densely occupied with large fluctuations in occupancy and ERV if occupancy is more consistent.

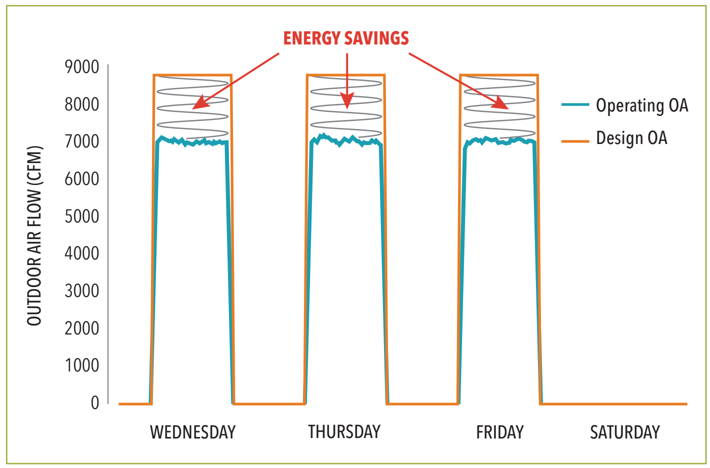

Figure 4: Monitored OA reduction from DCV

749 UNIVERSITY ROW SAVINGS FROM DEMAND CONTROL VENTILATION				
OA reduction	Fan savings	Cooling savings	Heating savings	Total energy saving
21%	46%	11%	9%	$0.27/CFM

(continued on page 3)

MAKING DEMAND CONTROL VENTILATION WORK

A key to making DCV systems work well is ensuring that designers, contractors, commissioning agents and building operators fully execute their responsibilities. Communication amongst all parties assures each knows their role in making the system work and has the information needed to do their job. This process begins with a thorough design that is commissioned after installation and monitored by the building operator.

- The designer should include specific lower and upper limits for outdoor air in design documents prior to installation. The CO_2 setpoint should also be specified. A setpoint between 900 ppm–1000 ppm is typical, but a more precise setpoint can be determined using ASHRAE 62.1 User's Manual, Appendix A. Higher setpoints result in greater energy savings, but could lead to indoor air quality issues if not properly selected.

- The designer should specify CO_2 and occupancy sensor placement, so that they represent the zone they serve. The CO_2 sensors should be located in a well-mixed area of the zone at a height of about six feet. The occupancy sensor should be placed so it doesn't see outside of the room, has a proper cover pattern, and isn't adjacent to a diffuser.

- The contractor should coordinate the handover from the design and construction team to the facility operator, including proper training on how to adjust the DCV sequence, locations of CO_2 and occupancy sensors, and how to monitor OA using the BAS system.

- The building operator should calibrate all CO_2 sensors annually to combat sensor drift.

- The commissioning agent should review major components of the design, ensure proper installation, and monitor OA and CO_2 rates for a short period immediately after initial operation.

- The commissioning agent should recommission existing DCV systems. Specifically, the commissioning agent should review OA flows compared to design OA, and modulation of OA flow compared to design sequences.

Other resources

ASHRAE 2010. 62.1 User's Manual ANSI/ASHRAE Standard 62.1 Appendix A.

Brandemuehl, M., and J. Braun. The Impact of Demand Controlled and Economizer Ventilation Strategies on Energy Use in Buildings. ASHRAE Transactions 105 (2): 39–50.

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