Demand-Controlled Ventilation and Sustainability

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A number of definitions exist for exactly what a sustainable design means for buildings. In essence, it involves a complete integrated building design that minimizes the impact on the environment and use of nonrenewable natural resources.

One technology for saving energy in HVAC systems is demand-controlled ventilation (DCV). DCV impacts overall building sustainability through influences on the total and peak energy consumption of the HVAC system and in indoor air quality (IAQ). For projects designed to achieve accreditation in the LEED® building certification program, points are possible via CO_2 monitoring (1 point) and perhaps as a contribution toward optimizing energy performance (2 points or more depending on the level of energy savings).

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The most common method to incorporate DCV into the design of an HVAC system is to adjust the amount of outdoor ventilation based on the level of CO_2 in the building air. The CO_2 level can be monitored by a sensor located in the occupied zone or in the return airstream, as shown in the generalized system configuration in *Figure 1*.

How DCV is integrated into a building's HVAC system is determined by system type. For example, adding DCV to a packaged rooftop unit may be a simple process of including the CO_2 sensor into a controller that has the DCV control logic built into it. Such a system likely may serve only one, or at most a few, occupied zones and, therefore, is simpler to control CO_2 levels. A larger building with central air handling may serve many different occupied zones and, thus, complicates where and how to locate the sensor(s). Determining the proper amount of outdoor air to bring in at the central air-handling unit also is complicated by the variable occupancy patterns within the multiple zones.

Energy Savings Comparisons

The biggest potential for energy savings with DCV is in building zones that vary widely in occupancy levels. When occupancy levels are low, the outdoor ventilation rate can be reduced to minimal levels and eliminate the need to condition additional and unnecessary outdoor air. Building zones such as auditoriums, conference rooms, restaurants, and retail stores are prime examples.

A variety of scenarios exist as reference points to compare energy used by an HVAC system with and without DCV. The choice of which to use is mostly determined by whether the evaluation is being made for new construction or for a retrofit.

New Construction

Comparison of ventilation air usage (and, thus, energy requirement to condition that air) should be to existing standards such as ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*. When performing the overall evaluation and estimation of energy savings, the inclusion of an enthalpy-based economizer should be done (if not done already). Economizer cooling likely is required by existing energy codes, depending on the building type, equipment size and locality. Even if economization is not required, it should be added with the DCV installation since both require the use of modulating outdoor air dampers and, thus, the additional cost impact is minimal.

Existing Building Retrofit

For an existing building, it is, of course, acceptable to compare the energy use of the system with DCV to one without DCV with a ventilation rate fixed to the levels set by Standard 62. Most published studies investigating the potential energy savings benefits of DCV are based on comparisons to a system that has ventilation levels set equal to criteria such as specified in ASHRAE Standard 62. However, this may not evaluate the true net impact on actual HVAC energy usage and indoor air quality since the building's HVAC system may have been constructed according to different ventilation requirements.

The ventilation flow also may be significantly different than originally planned due to later field alterations, equipment aging, etc. For example, the author has seen examples in the field where outdoor air intakes have been purposely blocked off (perhaps to save energy) and other situations where economizer controls with modulating air dampers were supposed to be installed but somehow never made it to the site (even though required by local code).

Regardless of the actual design standard, the evaluation of energy savings with DCV retrofitted into an existing building should first focus on a comparison to the existing building ventilation patterns even if they do not match current codes or standards. This is an approach that will give a clearer evaluation of the actual energy savings expectations to the building owner (or whoever pays the utility bills). If a building is not providing ventilation that meets existing standards, then the primary benefits with DCV are perhaps in the indoor air quality, as discussed in the next section.

The implementation of DCV to an existing building is site specific. If the system already has a modulating outdoor air damper with digital control, then the retrofit may be simple. However, if the site in question is older in design and construction, (for example if it has pneumatic-based controls), the retrofit will involve more changes and likely become difficult to justify strictly on energy economics.

Indoor Air Quality Impact

If the comparison is being made with respect to Standard 62, then *theoretically* the inclusion of DCV will not provide any improvement in indoor air quality. However, the ventilation flow rate per person (or per unit area in some buildings) set in Standard 62 does not include the impact of ventilation effectiveness in the building.

In general, for situations without significant other sources of air contamination, the standard sets recommended levels of ventilation per person to maintain an indoor CO_2 concentration of 700 ppm above ambient.

One way to improve the indoor air quality would be for ventilation airflow to be interpreted by the system designer as the amount actually delivered to the occupied zone, thus taking into account the ventilation effectiveness. In practice, however, these rates are taken as the total ventilation air delivered to the room.

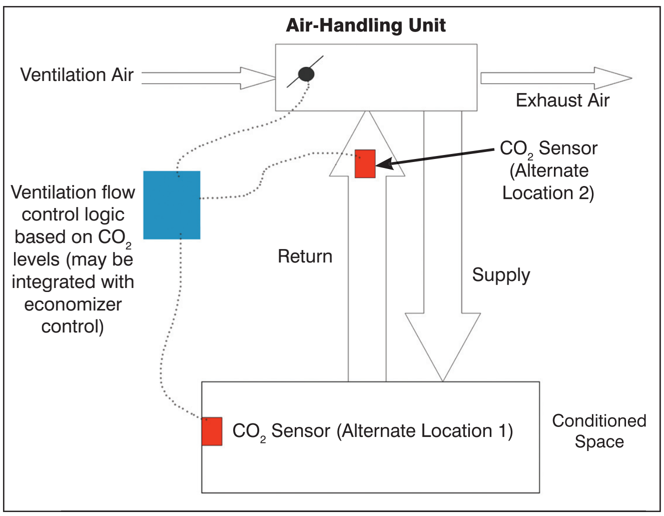

Figure 1: Generalized DCV integration into HVAC system.

Therefore, a system with DCV control could provide improved indoor air quality in situations where the occupancy is at or near design capacity and with typical room ventilation effectiveness values (0.6 to 0.8). In these cases, the energy consumption may actually be higher than if outdoor air ventilation rates were set to Standard 62 levels because the DCV controller will increase the outdoor airflow intake until the actual amount being delivered to the occupied zone brings CO_2 levels to the specified controller setpoint. If DCV is being considered as a retrofit for a building zone that has ventilation flow set lower than required by Standard 62, indoor air quality improvements are possible. The improvement in indoor air quality is potentially significant.

For example, consider a case studied recently at one large university in the United States. This study looked at the potential retrofit installation of DCV for two large classroom auditoriums, each with a maximum occupancy of about 300 persons and of similar size. Room A has an older mid-1970s HVAC system design and operates with an outdoor airflow rate of 1,500 cfm (700 L/s), or 5 cfm/person (2.4 L/s) at maximum occupancy. The other room recently had a system upgrade. The design ventilation flow rate is 3,750 cfm (1770 L/s) or about 12.5 cfm/person (5.9 L/s) at maximum occupancy. Both rooms include temperature based economizer control that provides additional outdoor air when the outside temperature is 56°F (13°C) or less.

A simplified analysis of the occupied zone concentrations in Room A, if steady-state conditions are assumed, indicates that CO_2 concentrations in excess of 2,500 ppm_v could occur. This analysis assumed a room ventilation effectiveness of 0.7 and room occupancy based on class schedules.

A comparison evaluated DCV control with a setpoint of 1,100 ppm_v (700 ppm above assumed ambient levels) against the existing setup and a scenario (labeled Time Schedule) where the ventilation air would be set to a constant 4,500 cfm (2100 L/s) (15 cfm/person [7 L/s]) during the normal occupied hours of the day. The predicted zone CO_2 concentrations are shown in the plot in *Figure 2*. Note that the Time Schedule case, using 15 cfm/person (7 L/s), should result in a zone concentration similar to the DCV setpoint during peak occupied hours of around 1,100 ppm_v. The actual predicted concentration is a little more than 1,300 ppm_v due to the inclusion of the effect of ventilation effectiveness and an assumed 500 cfm (240 L/s) of additional ventilation air due to infiltration.

Even if the building and equipment are relatively new, this does not necessarily mean that the actual ventilation air provided meets the criteria of Standard 62. Consider, for example, the use of portable classroom buildings widely prevalent in U.S. public schools. The actual ventilation air provided with a sidewall-mounted packaged unit using the standard factory issue fixed louver ventilation configuration was measured in classrooms at one field site to be only about 3 cfm per person (1.4 L/s).[1] The measured occupied zone CO_2 concentrations in these rooms with this amount of ventilation air routinely exceeded the sensor upper limit of 2,000 ppm_v during peak occupancy.

Summary

Demand-controlled ventilation has the potential to provide significant HVAC energy savings by conditioning only the amount of ventilation air necessary to maintain good indoor air quality. The most promising applications are in buildings or zones that have widely varying occupancy. DCV also has the potential for improving indoor air quality by automatically compensating for the effect of the room actual ventilation effectiveness. It is possible for these sustainable design improvements to be achieved with minimal additional equipment or system modifications.

When evaluating a site for application of DCV, the baseline used as a frame of reference in the comparison can significantly impact the level of expected energy savings and any improvement in indoor air quality. If a site has (or is assumed to have) constant outdoor ventilation equal to the levels specified in Standard 62, then significant energy savings are possible. Some improvement in indoor air quality also is possible by the compensation for ventilation effectiveness through the use of actual measured zone CO_2 concentrations. An existing site may have ventilation flow significantly different than current Standard 62 levels (usually lower). Therefore, the potential for *actual* energy savings may be less. However, a potential for improvement exists in indoor air quality due to the increase in actual ventilation flow provided.

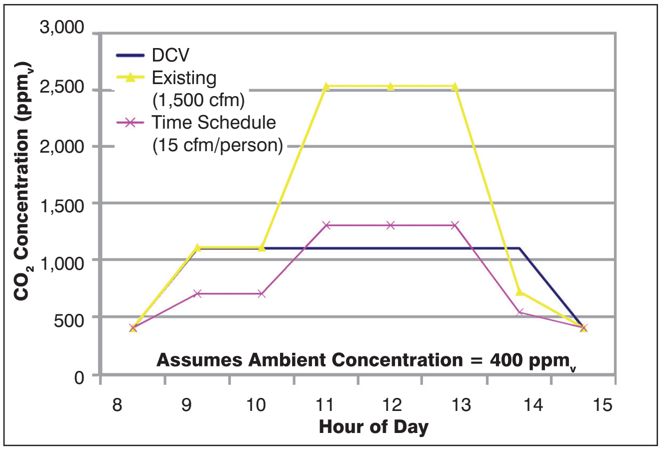

***Figure 2:** Predicted hourly average occupied zone CO_2 concentration.*

Reference

1. Lawrence, T.M. and J.E. Braun. 2003. "Ventilation effectiveness and indoor air quality at modular schoolrooms." CIBSE/ASHRAE Conference, Edinburgh, Scotland.

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