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Demand-Controlled Ventilation

Across the U.S., many stores keep long hours every day, and although they may be full of browsing shoppers during some hours of the week, relatively few customers will be milling about the floor space at other times. Occupancy fluctuations like these offer retail stores and other commercial facilities an opportunity for annual energy savings that can amount to as much as $1.00 per square foot ($ft^2$). Instead of continuously ventilating the space at a constant rate designed to accommodate the maximum number of customers, building operators can implement demand-controlled ventilation (DCV) so that the amount of outside air drawn in for ventilation depends on the building’s actual occupancy at any given time. This strategy results in energy savings because it reduces the amount of air that needs to be conditioned as well as the fan energy used to move that air. DCV primarily refers to when actual occupancies are approximated by measuring carbon dioxide (CO_2) levels within a building with sensors.

WHAT ARE THE OPTIONS?

this section

CO_2 sensor technology has improved substantially in recent years, and prices have dropped dramatically. Although these sensors ranged in price from $500 to more than $800 in the mid-1990's, some are now priced below $200, and several manufacturers offer CO_2 sensors bundled with temperature and humidity or dewpoint sensors in the same housing, which further reduces total costs. In addition, technological developments have resulted in sensors that remain accurate far longer than their predecessors, substantially reducing sensor calibration costs.

CO_2 sensors sold today use one of several types of self-calibration techniques to maintain the accuracy of their measurements, so they require calibration far less frequently than their predecessors did. As a result, several manufacturers now recommend that their sensors be calibrated no more often than once every 5 years, and two prominent manufacturers guarantee the calibration of their sensors over the devices' anticipated 10- to 15-year lives (**Table 1**). This contrasts starkly with earlier sensors, which required calibration every year—or even every few months. That high maintenance requirement was certainly labor-intensive, and it probably also resulted in periods of under- or overventilation due to sensor inaccuracy.

Table 1: Carbon dioxide sensor manufacturers

Each of these manufacturers offers at least one self-calibrating model.

Company	Recommended frequency of calibration	Cost per sensor	Telephone
AirTest Technologies	Never needs calibration over its 15-year lifetime	$150	888-855-8880
Digital Control Systems Inc.	5 years	$262	503-246-8110
Honeywell Control Products	5 years or more	$278	888-793-8193
Johnson Controls Inc.	5 years	$305	800-482-2778
Kele	3 years	$277	888-397-5353
Telaire Systems Inc. (GE)	Never needs calibration over its 15-year lifetime	$246	814-834-9140
Vaisala Inc.	5 years	$330	800-408-5266
Veris Industries Inc.	5 years	$378	800-354-8556

© E Source; data from manufacturers

Also on the technology front, several HVAC equipment manufacturers now offer DCV-ready rooftop units (RTUs) and variable-air-volume (VAV) boxes. This equipment is shipped with terminals for the CO2 sensor wires and controls that are preprogrammed to implement a DCV strategy. By limiting installation costs to those of mounting the sensor and running wires to the RTU or VAV box, DCV-ready HVAC equipment substantially reduces the cost of implementing DCV. Almost all RTUs built by Carrier Corp. and Trane that have economizers—about 60 percent of the RTUs these companies build—are also DCV-ready when shipped.

HOW TO MAKE THE BEST CHOICE

this section

To evaluate whether your building is a good candidate for DCV, determine if it fits one of the suitable facility types, then estimate potential savings using occupancy patterns and estimate the DCV implementation costs to calculate a payback period.

Select by facility type. Facilities that would likely reap energy savings with the use of DCV tend to have long operating hours, widely varying and largely unpredictable occupancy, and at least moderate annual heating or cooling loads. A very large number of facilities meet this description, including grocery stores, supermarkets, big-box stores, theaters, lecture halls and other performance spaces, places of worship, sports arenas, restaurants and bars of all types, and department stores. In fact, the majority of commercial facilities that are not now using DCV are at least potential targets for the technology (**Table 2**).

Table 2: Applicability of DCV by type of facility

This table, developed by HVAC manufacturer Carrier Corp., ranks the potential applicability of demand-controlled ventilation (DCV) by type of facility. Note that most facility types receive either a “recommended” rating, indicating that DCV will be advantageous for most facilities of that type, or a “possible” rating, indicating that site-specific factors must be considered and evaluated. Only a few types of facilities receive a “not recommended” rating, and the reasons are obvious for most of them. For example, the high concentration of volatile organic compounds present in an industrial painting and finishing facility would make it a poor candidate for DCV.

Rating: A = Recommended, B[a] = Possible, C = Not recommended

Application	Rating
Correctional facilities	
Cells	A
Dining halls[b]	B
Guard stations	C
Dry cleaners and laundries	
Commercial laundry	B
Commercial dry cleaner	C
Storage and pickup	B
Coin-operated laundries	A
Coin-operated dry cleaners	C
Education and schools	
Classrooms	A
Laboratories[d]	B
Training shops	B
Music rooms	A
Libraries	A
Locker rooms	C
Auditoriums	A
Smoking lounges[c]	B
Food and beverage service	
Dining rooms[b]	B
Cafeterias[b]	B
Bars, cocktail lounges[c]	B
Kitchens	C
Garages, repair and service stations	C
Specialty shops	
Barber and beauty	B
Reducing salons	B
Florists	B
Clothiers	B
Furniture	B
Hardware	B
Supermarkets	B
Pet shops	C
Sports and amusement	
Spectator areas	A
Industrial facilities	
Heavy manufacturing	C
Light manufacturing	B
Materials storage	C
Training facilities	C
Painting and finishing areas	C
Food and meat processing	C
Office buildings	A
Retail stores	
Sales floors	A
Dressing rooms	A
Malls and arcades	A
Shipping and receiving	C
Warehouses	C
Hospitals and medical facilities	
Patient rooms	B
Medical procedure	C
Operating rooms	C
Recovery and ICU	B
Autopsy rooms	C
Physical therapy	A
Lobbies and waiting areas	A
Hotels, resorts, and dormitories	
Bedrooms	B
Lobbies	A
Conference rooms	A
Meeting rooms	A
Ballrooms and assembly	A
Gambling casino	B
Game rooms	A
Ice arenas	A
Swimming pools	C
Gymnasiums	A
Ballrooms and discos	A
Bowling alleys	A
Theaters	A
Transportation	
Waiting rooms	A
Platforms	A

Notes: a. Applications listed as "possible" may be suitablefor demand-controlled ventilation. The system designer must evaluate additional factors such as building size and arrangement, type of HVAC system used, and separate requirements for control of contaminents not related to human occupancy.
b. DCV may be a suitable application, however, adequate ventilation and system balancing is necessary to maintain pressurization and odor control.
c. Designer must consider ventilation for cigar and cigarette smoke control.
d. Ventilation system design must consider requirements for odor and vapor control plus separate requirements for fume hoods.

Courtesy: Carrier Corp.

Among the facility types with a "recommended" rating in Table 2, some are much better candidates for DCV than others. For example, buildings that are larger, have higher occupant densities, and have higher variability in occupancy (such as auditoriums, sports arenas, large conference or meeting rooms, and ballrooms) are much more likely to yield significant energy savings and acceptable paybacks than smaller facilities (such as coin-operated laundries or dressing rooms).

Any facility designed to accommodate high occupancy—like most of those with a rating of "recommended" in the table—would be a great candidate as long as its actual occupancy is below design capacity most of the time. But there are also opportunities to implement DCV cost-effectively in facilities that have a "possible" rating. The best way to determine whether a given facility is a good candidate is to estimate potential energy savings using a computer simulation, which is referenced below.

Estimate occupancy patterns: Energy savings can be difficult to pin down, as they are highly dependent on both the maximum number of people a space is designed to accommodate (that is, the design occupancy) and the actual occupancy patterns on an average day—which can be difficult to determine. The difference between these two metrics reveals the opportunity for savings. For example, if a space is designed for 100 people, but actual occupancy falls as low as 30 people for several hours at a time, it may well be possible to dramatically reduce ventilation rates and reap savings.

So how can you determine whether your particular supermarket, restaurant, or casino is a good candidate? A good first cut would be to simply estimate occupancy on an hourly basis for a typical week in each season, and compare that data with the building's design occupancy, which will be specified by local building codes. Even better, if you can get hourly data from cash registers, you can use it to approximate occupancy by associating a given number of shoppers, theater-goers, or diners with each register transaction. With that information in hand and with knowledge of the facility's design occupancy, you can generate a reasonably good estimate of DCV's energy-saving potential using one of the evaluation tools downloaded free of charge off the Internet (**Table 3**).

Table 3: DCV evaluation tools

Each of these programs can be used to evaluate potential energy cost savings from demand-controlled ventilation (DCV). They are all available free of charge.

Company	Evaluation tool
Carrier	Hourly Analysis Program (HAP)
Honeywell	DCV Savings Estimator
AirTest	CO_2 Ventilation and Energy Analysis Program

© E Source

Measure occupancy patterns. If actual, estimated, or proxy data (for example, receipts) on occupancy aren't available, one low-cost way to determine the applicability of DCV is to use a portable CO_2 sensor to measure the effective ventilation rate for a given facility. Portable sensors coupled to dataloggers are available from several manufacturers at prices ranging from $550 to $700. These devices won't measure occupancy directly, but they will determine the effective ventilation rate per person, based on the difference between measured interior and ambient outdoor CO_2 concentrations.

To assess the viability of DCV in a particular facility, locate the portable sensor away from doors, windows, loading docks, and other potential sources of bias, and let it record for a period of at least one week. If CO_2 concentrations are below 800 parts per million (ppm) much of the time, the facility is probably a good candidate for DCV. Concentrations consistently above 1,000 ppm suggest that DCV is unlikely to provide much in the way of energy savings. However, if CO_2 concentrations rise above 1,500 ppm on a regular basis, DCV may be desirable for an entirely different purpose—air-quality improvement. If interior CO_2 concentrations are getting this high, it's probably an indication that body odors and pollutants—such as off-gassing from building materials, furniture, or other products—are accumulating, and occupant comfort could be improved by increasing ventilation.

If the actual design ventilation per person (pp) for a given facility is known, data from a portable CO_2 sensor can be used to estimate actual occupancy at any time. The CO_2 concentration inside a building is given by this equation:

$$CO_2\text{ in} = 10{,}600/\text{cfmpp} + CO_2\text{ out}$$

CO_2 in and CO_2 out represent the internal and external concentrations of CO_2 in ppm respectively, and cfmpp represents the per-person ventilation rate of the building. If you know the internal and external CO_2 concentrations, you can determine the actual ventilation rate of the building per person at any given time:

$$\text{cfmpp} = 10{,}600/(CO_2\text{ in} – CO_2\text{ out})$$

Dividing the building's design ventilation rate per person by this actual value allows you to determine occupancy of the building as a fraction of design occupancy. The resulting hourly occupancy estimates can then be used in any of the DCV savings evaluation tools discussed above.

Estimate the cost of installing DCV. To estimate return-on-investment or payback time using a savings evaluation tool, you will need to estimate the cost of installing one or more sensors and modifying HVAC controls to implement CO_2-based control. Today, individual sensors cost around $200 to $250; you will need a sensor for each RTU and/or each zone in the space—a minimum of one sensor for every 5,000 ft^2 of floor space (**Table 4**).

Table 4: Carbon dioxide sensor placement

This guide will help you determine the number and placement of carbon dioxide (CO_2) sensors that will be required to implement demand-controlled ventilation in any given facility.

	CO_2 sensors	
Building arrangement	One HVAC unit or system	Two or more HVAC units or systems
Single space, single zone Area less than 5,000 ft^2	One sensor	One sensor per unit
Single space, single zone Area larger than 5,000 ft^2	Quantity as required The area covered by each sensor should be less than 5,000 ft^2	One sensor per unit up to 5,000 ft^2
Multiple spaces, single zone Total area less than 5,000 ft^2	One sensor Locate sensor in space that is most ventilation sensitive	One sensor per unit
Multiple spaces, single zone Total area larger than 5,000 ft^2	One sensor per space	One sensor per unit
Multiple spaces, multiple zones	One sensor per zone	One sensor per zone

Note: ft^2 = square feet.

Courtesy: Carrier Corp.

Implementing DCV on a newer DCV-ready RTU with an existing economizer will cost between $300 and $900 per RTU. The lower end of this range would apply where installation amounts to no more than wiring the sensor into the existing RTU terminals. Installation costs will rise to the higher end of this range when a digital controller is needed to interface with the RTU.

If you've got an old economizer, it's cheaper and more reliable to replace the electronic components than to create an interface with older technology. The cost of replacing the economizer motor, controller, and enthalpy sensors and implementing DCV ranges from $1,500/RTU for multiple RTUs to $2,000 for a single RTU. Costs will be higher if the entire economizer needs to be replaced or if the RTU is not equipped with an economizer. In either case, the added benefits from having a properly working economizer (independent of DCV) would also need to be factored into any calculation of cost-effectiveness.

WHAT'S ON THE HORIZON?

this section

As changes to the ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) Standard 62, "Ventilation for Acceptable Indoor Air Quality" (adopted in 2003), filter down into local building codes, opportunities to implement DCV will decrease somewhat because minimum required ventilation rates have increased, thereby reducing potential savings. However, DCV will remain a cost-effective control strategy for a wide variety of commercial establishments, especially those with widely fluctuating or unpredictable occupancy levels.

WHO ARE THE MANUFACTURERS?

this section

Sensor manufacturers

- AirTest Technologies Inc.
- Cemtrex
- Digital Control Systems Inc.
- Gesensing
- Honeywell Control Products
- Johnson Controls Inc.
- Vaisala
- Veris Industries Inc.

DCV-ready equipment

- Carrier
- Daikin Applied
- Trane
- York

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