VOLUME THREE NUMBER FOUR

SYNOPSIS

AN HVAC NEWSLETTER FOR BUILDING OWNERS AND MANAGERS

In this issue...

Want to know more about Demand Controlled Ventilation?

Call 1-800-CARRIER and request the publication *HVAC Analysis,* Vol. 3, No. 4, written specifically for consulting engineers, or visit our web site at www.carrier.com

Improve Indoor Air Quality and Reduce Costs With Demand Controlled Ventilation

Building owners and managers have many issues to weigh when selecting heating, ventilation and air conditioning (HVAC) systems. Occupant comfort, safety and compliance with regulatory standards are primary considerations. Meeting these needs while containing operating costs is a constant challenge.

This is particularly true when deciding on ventilation strategies and methods to regulate the amount of outside air brought into your building. In recent years, demand controlled ventilation (DCV) using carbon dioxide sensing technology has emerged as an effective and affordable way to optimize outside air quantities to maintain comfort and indoor air quality (IAQ). It is now recognized as a viable method to comply with ASHRAE Standard 62-1999, "Ventilation for Acceptable Indoor Air Quality."

Ventilation On Demand

Many buildings are over- or under-ventilated, wasting significant amounts of energy and creating uncomfortable environments. One of the main reasons for over-ventilation is that systems are designed for maximum occupancy levels, which rarely occur in a typical building. If the system cannot detect changes in occupancy, it will over-ventilate most of the time,

continued on page 2

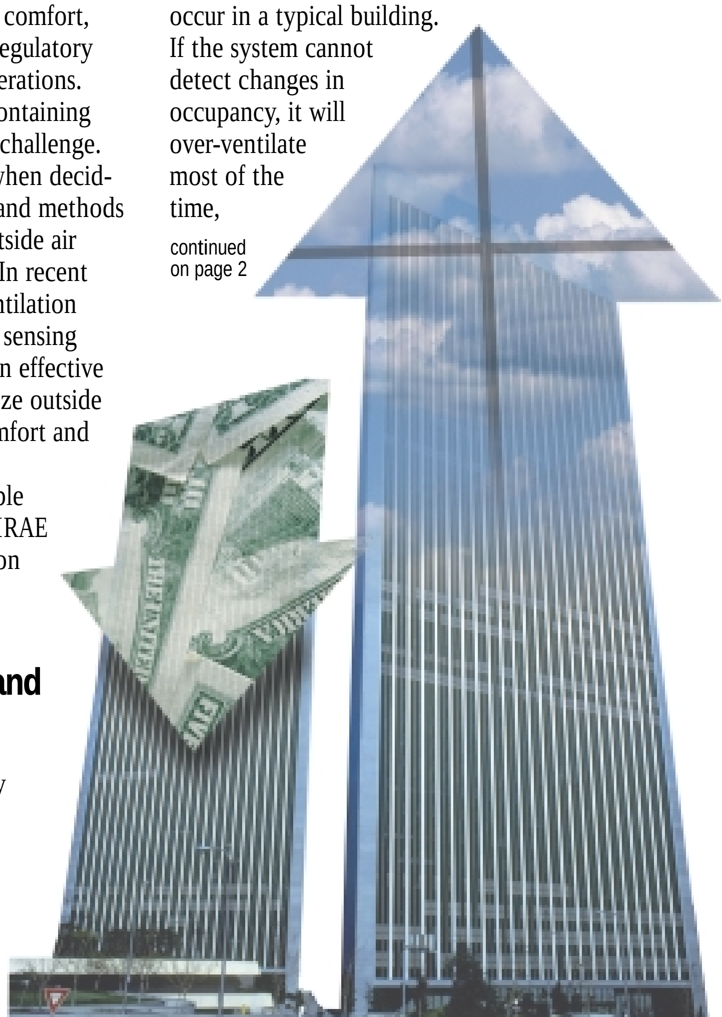
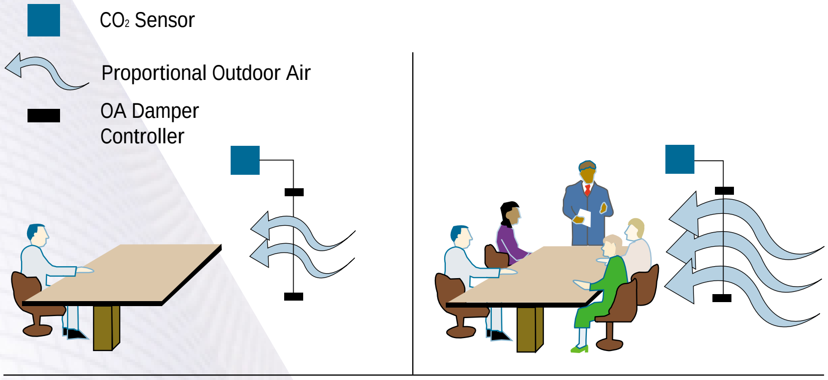


FIGURE 1 **Amount of Outside Air Controlled to Match the Occupancy of the Room**



VENTILATION: A COMBINATION OF PROCESSES

In the past, natural ventilation was typical – if an office was stuffy, you just opened a window. Most of today's commercial buildings are built without operable windows, so mechanical ventilation systems are needed to exchange indoor air with fresh air from outside. Adequate ventilation increases comfort and prevents the build-up of harmful contaminants that have been linked to drowsiness, lethargy and headaches. To optimize air balance and movement within a building, ventilation and air handling systems typically:

- Bring outside air into the building
- Condition and/or mix the outdoor air with some portion of the indoor air
- Distribute the mixed air throughout the building
- Exhaust some portion of the indoor air outside
- Bring in more outside air as "make-up" air

bringing in much more outdoor air than is required. This not only results in unnecessary utility costs, but can cause coils to freeze in colder climates and unacceptably high humidity in warmer, southern regions. Under-ventilation can result from overzealous attempts to reduce energy costs or from poor equipment maintenance. This can create a dangerous buildup of air contaminants.

DCV controls the ventilation airflow rate based on actual building occupancy. It delivers just the right amount of outside air, where and when it is needed. To do this, it needs constant information about occupancy levels. Carbon dioxide (CO_2) sensors, using intelligent microprocessors, are now available to do this job accurately and cost-effectively.

CO_2 is a product of human respiration, released into the air at a predictable rate as people exhale – an excellent indicator of how many people are in a space. CO_2 levels in outside air are also predictable and are typically very low. Therefore, bringing outside air into a building "dilutes" the indoor CO_2 levels. By comparing outside and inside CO_2 concentrations, the amount of outside air being introduced can be calculated, as well as whether that amount is providing appropriate ventilation for comfort and health.

Just as thermostats control how much heating or cooling is supplied to a space, DCV with CO_2 sensors allows a building's HVAC system to control the supply of outdoor air (Figure 1). Conventional ventilation control forces the outdoor air intake dampers open, allowing the full amount of ventilation, which would be required only if the space were fully occupied. It doesn't allow for the wide variation in occupancy during the course of a typical business day. In contrast, DCV, by delivering outdoor air for the actual occupant load rather than a predetermined maximum, provides substantial energy savings (Figure 2).

Occupant comfort, health, safety and compliance with regulatory standards are primary considerations.

Setting the Standard for Building Ventilation

ASHRAE Standard 62-1999 (superceding Standard 62-1989) specifies minimum ventilation rates and sets indoor air quality standards intended to minimize health risks for human occupants. The standard designates required outdoor air ventilation, expressed in cfm (cubic feet per minute) per person. These requirements are application specific – they vary according to what activities people in the space are engaged in – and are calculated using estimated maximum occupancy levels (Figure 3).

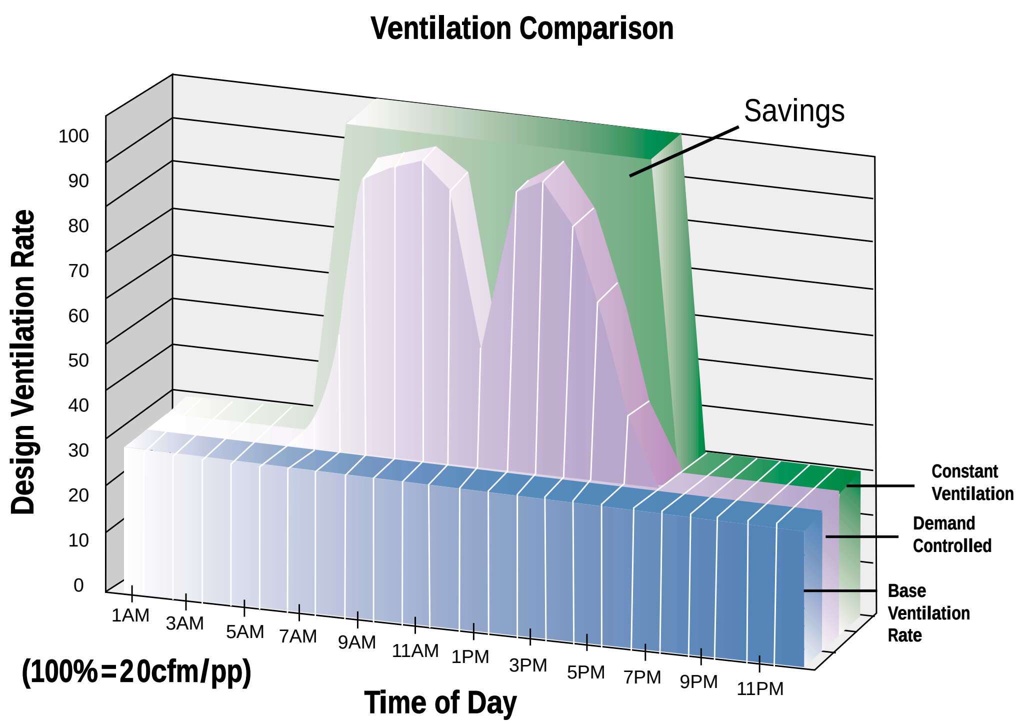
Multiple Spaces

In buildings where multiple zones share a common supply air system, the zone requiring the highest percentage of outdoor air – the critical zone – would normally determine the quantity of outside air supplied to the entire building. The ASHRAE standard provides an equation that may be used to reduce the quantity to a level below the percentage of outdoor-to-total-supply air required by the critical space.

Even though the standard clarifies this process in an appendix, and provides for the recirculation of unused non-critical space outdoor air, the multiple spaces equation is problematic, especially for variable air volume (VAV) systems. Because all values are assumed, the calculation may not be relevant to what is really happening in the space. In addition, there is very little flexibility if occupancy patterns change from what is originally assumed by the design engineer. It is also difficult to verify that a system using the multiple spaces approach is actually working as designed, and whether the design is appropriate for the space.

Dynamically tracking the amount of outdoor air against the total supply air to ensure sufficient ventilation is a challenge. A much better approach is to use zoned demand controlled ventilation. With this method, the zone calling for the most outdoor air drives both the zone airflow and the system outdoor air dampers to meet its local setpoint. Unused ventilation is automatically incorporated into the recirculated return air.

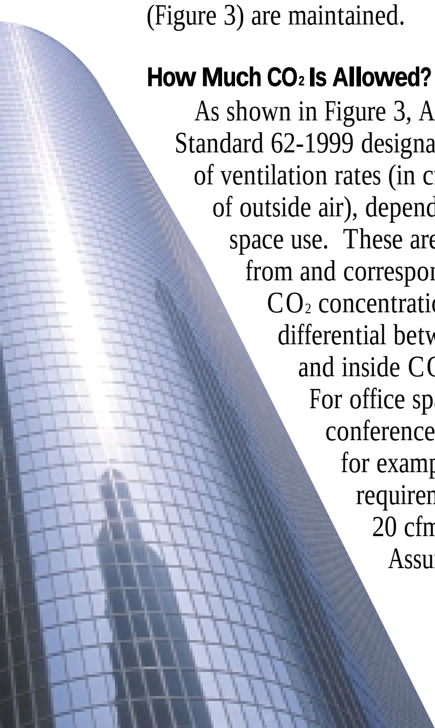
FIGURE 2



Intermittent Or Variable Occupancy

The standard also allows for adjustments of outdoor air quantities for spaces with intermittent or variable occupancy levels. It permits the use of dampers or fan cycling to modulate outside air, provided that acceptable contaminant concentrations are maintained at all times. This section of the standard opens the door for CO_2-based control systems to be used for automatic outdoor air adjustment based on actual occupancy, as long as the per-person ventilation rates in Table 2 (Figure 3) are maintained.

How Much CO_2 Is Allowed?



As shown in Figure 3, ASHRAE Standard 62-1999 designates a range of ventilation rates (in cfm/person of outside air), depending on the space use. These are derived from and correspond to indoor CO_2 concentrations and the differential between outside and inside CO_2 levels. For office space and conference rooms, for example, the requirement is 20 cfm/person. Assuming an outdoor CO_2 concentration of 400 ppm, this corresponds to an indoor concentration of XXXX ppm and an outdoor/indoor differential of XXX ppm.

Demand controlled ventilation continually measures outdoor and indoor CO_2 concentration levels. By calculating the occupancy level of the space and the differential between outside and inside CO_2 levels, the ventilation rate per person can be determined and compared to the standard's requirements. (As an alternative to actual measurement, the standard allows for an established outdoor air CO_2 value to be used.)

Demand controlled ventilation continually measures outdoor and indoor CO_2 concentration levels.

It is important to note that in using CO_2 sensing for DCV, the CO_2 is an indicator only and is not considered as a contaminant. For this reason, indoor concentrations are used more for comparison and calculation purposes than as gauges of indoor air quality. To use the same example, if the outdoor CO_2 concentration were higher than typical – say 550 ppm due to high vehicle traffic near the building – the target 20 cfm per person could be achieved, yet the indoor CO_2 concentration would be higher – about 1250 ppm. This is an acceptable scenario within the guidelines of the standard.

Similarly, it should not be assumed that relatively low indoor CO_2 concentrations indicate good indoor air quality. Other contaminants may be present that have built up during unoccupied hours. For this reason, additional control strategies should be implemented to monitor and address IAQ issues. In addition, a "base ventilation" rate should be established for unoccupied periods. Suggested levels for base ventilation range from 15 to 50% of the design rate for buildings more than a year old. Newer buildings, or those that have been extensively renovated, tend to experience off-gassing from new building materials, carpet and furnishings, and require more ventilation.

WHY CO2 SENSORS ARE GOOD "PEOPLE METERS"

Carbon Dioxide is a gas, found naturally in the earth's atmosphere. It is typically measured in parts per million (ppm), designating the number of CO_2 molecules per million molecules of air. Outdoor air (in urban areas) typically contains about 400 – 450 ppm of CO_2, whereas the average adult's breath contains 35,000 – 50,000 ppm. CO_2 is ideal for determining building occupancy levels for these reasons:

- CO_2 concentrations are easily measured, both outdoors and indoors
- People exhale CO_2 at predictable rates, given their activity levels
- CO_2 is an inert gas that does not readily react with other gases and degrades slowly

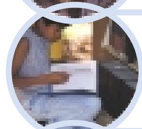
Cfm/person of ventilation air can be readily calculated when these three things are known:

- CO_2 concentration of outside air
- CO_2 concentration of inside air
- Per-person rate of CO_2 generation

FIGURE 3

Outdoor Air Requirements for Ventilation*






Application	Estimated Maximum Occupancy (people/1000 ft2)	Outdoor Air Requirements (cfm/person)
2.1 Commercial Facilities		
Offices		
Office space	7	20
Reception areas	60	15
Conference rooms	50	20
Retail Stores/Sales Floors		
Hardware, drugs, fabric	8	15
Supermarkets	8	15
2.2 Institutional Facilities		
Education		
Classroom	50	15
Laboratories	30	20
Libraries	20	15
Hospitals/Nursing Homes		
Patient rooms	10	25
Medical procedure	20	15
Operating rooms	20	30

* Table 2 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

Information from ASHRAE Standard 62-1999, Table 2 – for the complete table, including comments, see the standard.

Lag Time

The standard also sets acceptable lag time parameters. Lag time is the time it takes the system to adjust outdoor air intake to achieve the target per-person ventilation rate following an unoccupied period. Allowable lag times are a function of both the required ventilation cfm per person and the total volume of air in the room per person. The larger the room – and the volume of air it contains (space volume) – the longer the permissible lag time. For example, in a space where 15 cfm/person of outdoor air is required, the allowable lag time could be as short as six minutes (for a room with 100 cubic feet of space volume per person) or as long as two hours (for a room with 1,500 cubic feet of space volume per person).

Ventilation Effectiveness

The effectiveness of a building's ventilation is determined by the amount of outside air intended for the space that actually reaches the occupants of the space. This amount is typically expressed as a percentage. Ventilation effectiveness can fall below 100% because of improper supply diffuser and return grill placement. It is possible for some of the supply air to be "short circuited" to the return air without ever having entered the occupied area of the room. Another cause of reduced effectiveness is imperfect air mixing. The correct amount of outside air may be brought in, but the mixing process does not result in the anticipated percentage of outside air entering the occupied space.

Because a DCV system is continually monitoring CO_2 levels, it can detect and automatically correct for reduced ventilation effectiveness. In contrast, other methods of ventilation typically rely on estimated ventilation effectiveness values, which may or may not be accurate at any given time.

Implementing DCV

Control technology has come a long way in recent years. Accurate, reliable and affordable sensors are now readily available, with features such as automatic calibration and integrated thermostats (Figure 4). In addition, demand controlled ventilation can be incorporated into the building's Energy Management System as part of a complete package of IAQ control and optmized building system operation.

FIGURE 4

continued on page 5

continued from page 4

Outdoor Air Sensors

CO_2-based DCV uses a differential comparison of outdoor and indoor CO_2 concentrations to maintain proper ventilation rates. So it's important to have an accurate outside air measurement. In most locations, the outdoor CO_2 concentration is fairly stable, varying less than 100 ppm from its nominal value. However, CO_2 levels will increase when significant combustion fumes are present. These can come from loading docks or other sources of steady vehicle traffic, rooftop gas heaters or other combustion exhaust. If possible, outdoor air intakes should be located well away from these sources.

It's important to have an accurate outside air measurement.

Similarly, CO_2 levels tend to be consistently higher in locations near major highways or in cities with significant pollution. A CO_2 sensor should be used to monitor the outdoor air for contamination from fossil fuel combustion and to establish, track and verify the nominal CO_2 level.

Indoor Air Sensors

Criteria for selecting indoor CO_2 sensor locations will vary from building to building, depending on system type and space layout. Sensor placement should be evaluated during system design, at start-up and on a continuing basis for effective ventilation results with respect to:

- design ventilation rate on full opening of the outdoor air intake;
- base ventilation rate on full throttling of the outdoor air intake;
- lag time when increased outdoor air intake is called for.

Wall-mounted sensors are recommended for DCV applications. They should be installed in locations similar to thermostats – and should provide input that accurately represents conditions in the zone. Avoid placement near doorways, air vents and areas that are within one foot of where people would normally sit or stand. When using one sensor to represent a large area, the location most critical for ventilation rate delivery should be selected. Wall-mounted sensors can be used with single zone, constant volume systems; and multiple zone, constant and variable volume systems.

The use of duct-mounted sensors for DCV is not recommended, especially for systems serving a number of areas with diverse occupancy. A sensor located in the return duct of a single zone, constant volume air handling system can be acceptable if all the spaces served by the air handler have similar levels of activity and occupant densities, occurring at the same time.

Return duct-mounted sensors are subject to error, however, due to building infiltration, supply duct leakage or short-circuiting of supply air back into the return. If this location is chosen, it should be tested during an occupied period by measuring the CO_2 level in the space while the equipment is operating. If this reading is not the same as that of the duct-mounted sensor, the air leakage path must be corrected or the sensor relocated.

Energy Savings

Demand controlled ventilation is an effective way to substantially reduce energy costs. These savings can be calculated using a weather bin analysis for your building's local climate. A "base case" can be developed using outdoor air quantity for maximum occupancy (design) conditions, along with occupancy start and end times. For the DCV case, hourly occupancy profiles are input. The analysis establishes the "avoided amount" of outdoor air, which would require conditioning with the conventional, base case scenario. Because DCV reduces the amount of outside air when conditions permit, less energy dollars are needed to heat or cool it. Computerized programs are available to perform this analysis.

Demand controlled ventilation is a cost-effective method to provide optimized outside air for the varying ventilation needs of your building's occupied spaces. Payback periods for a DCV investment have been shown to be between six months and two years.

Carrier's DCV Solution

Carrier has developed a zone controller that incorporates DCV ventilation control with standard variable air volume (VAV) temperature control (Figure 5). The ComfortID System receives input signals from space-mounted thermostats and CO_2 sensors and responds with output signals to control the VAV box for both thermal and IAQ comfort.

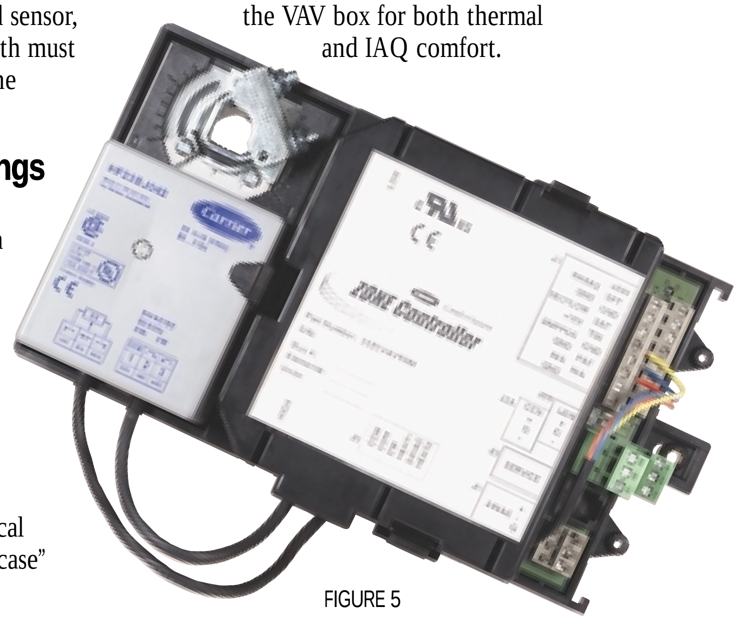


FIGURE 5

BASING SUPPLY ON DEMAND YIELDS BIG BENEFITS

With CO_2-based DCV, building owners and managers can save energy dollars, while still providing ventilation that promotes indoor air quality and complies with ASHRAE Standard 62-1999. Benefits include:

- Saves money by reducing costly over-ventilation when spaces are partially or intermittently occupied
- Continually monitors and adjusts outside air to maintain target per-person ventilation rates
- Takes into consideration outdoor air introduced by natural ventilation from air leakage, open windows, etc., and reduces mechanical ventilation accordingly
- Can be adjusted to maintain any desire ventilation rate
- Improves control of indoor comfort by reducing air intake when feasible under extreme outdoor conditions – controls humidity in hot, humid clmates; maintains humidity in cold conditions

ComfortID, when combined with the Carrier Comfort Network® (CCN), optimizes building system operation and provides a complete IAQ control solution (Figure 6). Identifying critical building zones reported by the zone controllers, CCN directs the primary HVAC system to respond. The system can optimize the central air handler's outdoor air damper intake in conjunction with the zone airflow, to maximize efficiency, while providing enough outdoor air to meet the ventilation requirement of each zone.

In addition, Carrier offers a computerized program to analyze the potential energy savings of a DCV system for your building.

Conclusion

Demand controlled ventilation offers a cost-effective approach that allows you to get the most from your building's ventilation system. By precisely matching the amount of outside air to actual occupancy, you conserve energy and save money, while providing a comfortable indoor environment that complies with industry standards for optimal ventilation rates.

FIGURE 6

The ComfortID Solution