GETTING MORE FOR LESS

HOW DEMAND CONTROLLED VENTILATION INCREASES AIR QUALITY AND REDUCES COSTS

By: John J. Lauria, III
Carrier Corporation
Farmington, Connecticut

December 1998

DCV: A BETTER ALTERNATIVE

Traditionally, the HVAC industry has complied with ASHRAE's standards for indoor air quality with constant ventilation, a control that maintains a desired ventilation setpoint based on the design occupancy of the space. But this method often results in significant wastes of energy - and energy dollars.

In contrast, Demand Controlled Ventilation (DCV) uses CO_2 sensors to supply outdoor air based on the actual occupancy of the room - the demand. In the process, it increases indoor air quality and the saves energy normally wasted in ventilating unoccupied spaces.

To understand this more clearly, let's first look at the ASHRAE standard.

MAINTAINING IAQ

ASHRAE recently approved a new revision to "Ventilation for Acceptable Indoor Air Quality," the American national standard also known as Standard 62-1989, and its addendum, 62a-1990.

The organization also proposed and published Standard 62-1989R, which has since been officially withdrawn. Standard 62-1989 is currently on "continuous maintenance," and specific series of changes are being made to it.

ASHRAE Standard 62-1989 and addendum 62a-1990 provide outdoor air requirements based on application, estimated design occupancy and CFM per person. (See Table 2 of the ASHRAE standard.) They also include requirements for variable occupancy spaces such as corridors, retail floor space, malls, etc., defined in outside air per square foot.

In section 5.4, the standard states that when the supply of air is reduced while the space is occupied (as in VAV systems), provisions must be made to maintain acceptable indoor air quality throughout the occupied zone. According to ASHRAE, this may be accomplished in one of two ways:

- Ventilation Rate Procedure 6.1, in which acceptable air quality is achieved by supplying ventilation air of specified quality and quantity to the space.
- Ventilation Rate Procedure 6.2, an alternative performance method for achieving acceptable air quality.

VENTILATION RATE PROCEDURE 6.1

The formula for ventilation rate procedure 6.1 - promoted by some of our competitors - is described in ASHRAE 62-1989, paragraph 6.1.3.1., "Multiple Spaces." It requires that the control system monitor the CFM being delivered to each zone and compare it to a configured outdoor air CFM setpoint for that zone.

It then selects the worst, or most critical, space and feeds parameters into ASHRAE's equation 6.1 to calculate the amount of outdoor air required, taking into account the uncorrected fraction of outdoor air in the system supply and the fraction of outdoor air in the critical space. This control scheme's equations require:

- The zone airflow be measured dynamically for each zone.
- The outdoor air CFM setpoint be stored for each zone.
- An accurate air flow station be properly installed in the outdoor air duct.
- A suitable transducer be purchased that can accurately measure extremely low duct velocity pressures.
- Totalization of zone CFM, locate the worst case zone, and interface to the air handler's mixed air dampers.

To comply with the ASHRAE standard, the design engineer estimates the amount of outdoor air required in each space in CFM per person or per square foot, using Table 2 of the ASHRAE Standard. As thermal load changes in the space, the outdoor air damper position is slightly modified to compensate for the increase or decrease of load.

This constant ventilation method will perform adequately in applications where there are no spaces with significant occupancy density changes.

In spaces where significant occupancy density changes do occur, the minimum outdoor air requirements are still very large (typically 15 to 20 CFM per person based on maximum occupancy, although it may be higher). In these cases, the design requirements for a high minimum outdoor air CFM setpoint require a high percentage of the total system airflow to be outdoor air, even under maximum load.

Consequently, when a space is under-occupied, this system over-ventilates. But more seriously, it causes the outdoor air intake to be excessively high, even approaching 100%. This can result in freezing coils in colder climates or high space humidity in warmer, southern climates, as well as massive energy waste.

Why does this happen? Because the thermal load of the space is minimal, but the required outdoor air CFM is sized for maximum design occupancy. When put into ASHRAE equation 6.1, this situation results in the outdoor intake being increased to nearly 100% to get the full amount of required outdoor air into the space, which is at minimum airflow.

Significant amounts of energy are wasted when the system brings in a large percentage of outdoor air and feeds it into the entire system. In addition, attempting to reduce the percentage of outdoor air by increasing minimum airflow requires terminal reheat to maintain temperature control in spaces where the airflow exceeds the amount required.

HOW DOES DEMAND CONTROLLED VENTILATION DIFFER?

Demand Controlled Ventilation allows end users to maintain proper ventilation and improve air quality levels through the use of CO_2 sensors. The sensors operate as "people meters" to maintain ventilation based on the actual occupancy of the space.

It should be noted that an interpretation of ASHRAE standard 62-1989 (subclause 6.1.3, section 6.1.3.4), considered January 26, 1997, states:

"...it is consistent with the Ventilation rate procedure that Demand Control be permitted for use to reduce the total outdoor air supply during periods of less occupancy...."

This means individual zone ventilation control using CO_2 sensors can be applied to such critical areas as conference rooms, board rooms, cafeterias and other spaces with frequent changes in occupancy.

VENTILATION RATE PROCEDURE 6.2

Direct Controlled Ventilation must control whenever the air handler is operating and any of its associated spaces are occupied, including during mechanical cooling, fan only or heating modes.

As you can see from Figure 1, DCV can show significant energy savings while providing temperature control and CO_2-controlled ventilation.

In fact, when the cost of air flow station transducers (Varitrac dampers) and duct installation work is compared to the cost of individual CO_2 sensors, a fully equipped DCV system may very well be at or below the cost of constant ventilation (equation 6.1).

Zone ventilation control allows modulation of the terminal air flow in response to increasing levels of CO_2 from a local CO_2 sensor. These applications require that a 0-2000ppm CO_2 sensor with a 4-20ma output be connected to the air terminal controller. By properly calculating and adjusting the CO_2 equilibrium setpoint for a particular zone, the control can then be configured to provide DCV.

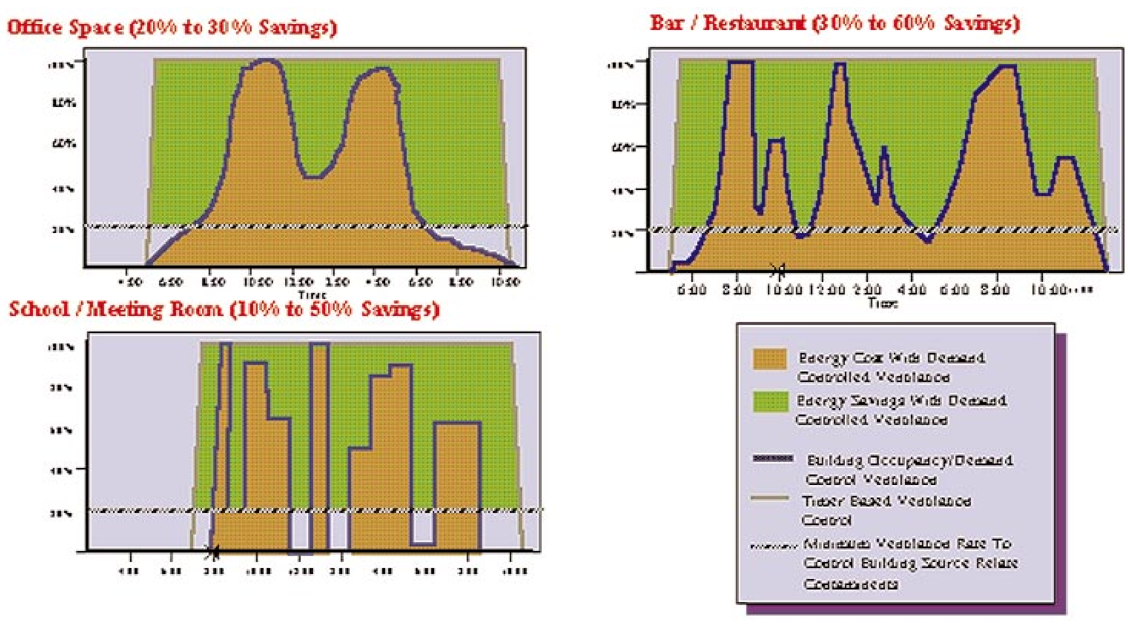
To prevent overcooling, the maximum ventilation CFM can also be configured for each zone. A feature of Carrier's control system is that the IAQ maximum zone ventilation CFM may be a different value than the normal maximum zone CFM used for temperature control.

This strategy provides a way to maintain the zone's required ventilation rate using a sensor with a repeatable output - unlike VOC sensors, which are affected by a large number of pollutants to differing degrees, and with unidentifiable responses to each.

To create a fully integrated IAQ control system, the highest CO_2 sensor reading can be used by the air handler controller to adjust the outdoor air intake. The air handling unit's outdoor air damper can then automatically modulate and control to the highest zone ventilation requirement without dedicated inputs at each AHU controller for each zone. The air handler will only increase its outdoor air intake after the zone has reached the maximum configured ventilation CFM setpoint.

The Demand Controlled Ventilation system is dynamically flexible, adapting as needed to the movement of people within the building and providing a high comfort level. As more people occupy a space, the system increases the terminal airflow until either the

ventilation requirement is satisfied, or the zone



▲ Figure 1 - Typical Energy Savings with CO_2 – Based Demand Controlled Ventilation temperature starts to become adversely affected by the increased airflow.

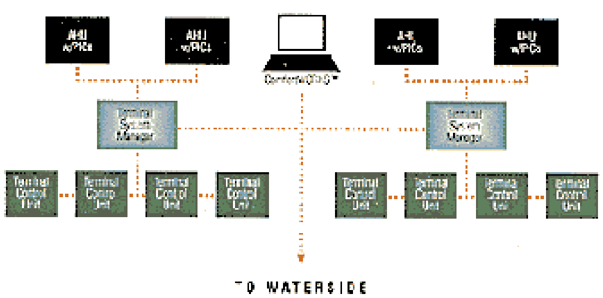
When maximum ventilation airflow setpoints are reached, the air handler supplies more outside air to the space. Over time, the system automatically adjusts to a point where the air terminal flow is maintaining zone temperature, while the AHU's mixed air damper position is meeting the zone's ventilation requirement.

In addition, constant outdoor air control can be used in conjunction with VOC sensors to insure that proper ventilation is provided for outgassing of materials.

PRODUCTS THAT SUPPORT DCV

Carrier's Digital Air Volume (DAV) system (see Figure 2) is a pressure-independent, integrated VAV control that evaluates and supports the equipment operation necessary to satisfy space or zone requirements.

It controls the operation of the terminal boxes within the individual spaces to maintain temperature, as well as such IAQ parameters as relative humidity or proper outdoor air ventilation requirements. DAV also directs the operation of zone equipment to fill particular system requirements, such as smoke control.



▲ Figure 2 - Carrier Digital Air Volume (DAV) Control System Overview

The Carrier Comfort System AirManager air handler control can support air quality sensors, which can be implemented for ventilation requirements from the associated zones or as return duct-mounted VOC, CO_2 or other IAQ sensor inputs.

Carrier Comfort System AirManager

FEWER OCCUPANTS, LOWER COSTS

Tables 1 and 2 (Appendix A) clearly contrast the two ventilation control methods approved by ASHRAE. As an example, let's use a conference room sized for 14 people.

Refer to the top line of Table 1, which represents equation 6.1, constant volume control. Note that whenever the conference room has been indexed to an occupied mode, it must be supplied with the cumulative total of the per-person ventilation rate, which works out to 280 CFM of outdoor air (14 occupants x 20 CFM per person). Even when the conference room is occupied by only two people, equation 6.1 requires 280 CFM of outdoor air.

Table 2 (Appendix A)represents Demand Controlled Ventilation. As part of Carrier's DCV scheme, we are first able to calculate a CO_2 equilibrium setpoint based on the following formulas:

$$\triangle CO_2 = \frac{8400 \times M^*}{\text{CFM per person}}$$

$$CO_2 \text{ Setpoint} = \triangle CO_2 + \text{OA } CO_2$$

** M represents physical activity in MET units, which varies depending on expected building use and activity. Different values (office average = 1.2, seated activity = 1.0, etc.) may be found in Appendix D of the ASHRAE standard.*

With a calculated CO_2 setpoint, the ventilation rate is established on a per-person basis, enabling the Carrier DAV system to automatically adjust the ventilation rate based on the actual number of occupants, as shown in Table 2 of the Appendix.

Note also that at 14 occupants, the Carrier DAV system is required to deliver the same amount of outdoor air ventilation as in ventilation rate procedure 6.1, yet substantial energy savings (not including the additional cost of reheat) are realized whenever the conference room is occupied with fewer than 14 people.

CONSTANT VENTILATION FOR VAV SYSTEMS WITHOUT CO_2 SENSORS

Since it's not always possible or practical to supply individual zone ventilation controls, a Carrier DAV system can also maintain the minimum zone outdoor air CFM for each zone.

Based on the engineer's calculations and the HVAC mechanical plan schedule, we can calculate the offset for fixed exhaust and outdoor air necessary for a positive pressure. Through an outdoor air flow measuring station, the air handler will modulate a damper output to maintain a minimum outdoor air CFM of 2900. At this point, we can calculate the minimum zone CFM requirement for a typical zone as follows:

SF nominal CFM = 13,200
RF nominal CFM = 10,300
$\triangle$ CFM = 2,900

$$OA\% = \frac{2{,}900}{13{,}200} = 21.9\%$$

Although this scenario meets the ASHRAE standard requirements, the system will over-ventilate whenever it is not at design load.

CLEARING THE AIR

According to an editorial in the March 1997 issue of Engineered Systems, some common approaches to ventilation control can lead to excessive air intake and the potential for massive energy waste.

Carrier believes individual zoned ventilation control is a more dynamic ventilation method, one that automatically adapts to the movement of occupants in a building and delivers a high level of comfort in the process.

Simply put, zoned air quality control is provided by modulating the terminal airflow in response to both temperature and indoor air CO_2 levels, all in conjunction with the air handling equipment's outdoor air damper. The result is increased indoor air quality, reduced energy usage and lower operating costs.

SOURCES

John J. Lauria, III
Carrier Corporation, Farmington, CT
Phone: 860-674-3052
E-mail: john.lauria@carrier.utc.com

ASHRAE-62-1989 and Addendum 62a-1990

American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
1791 Tullie Circle NE
Atlanta, GA 30329
Phone: 404-636-8400 Fax: 404-321-5478

APPENDIX A

ASHRAE 62 WITHOUT CO_2 DCV (TABLE 1)

Occupancy Level	R Vp	Sq.Ft.	DVR Vt	CO_2 Control	CO_2	Actual VT	+/- CFM	% Reg Vt	% Saving
14	20	280	280	No	0	280	0	100.0	0.0
13	20	280	260	No	0	280	20	107.7	0.0
12	20	280	240	No	0	280	40	116.7	0.0
11	20	280	220	No	0	280	60	127.3	0.0
10	20	280	200	No	0	280	80	140.0	0.0
9	20	280	180	No	0	280	100	155.6	0.0
8	20	280	160	No	0	280	120	175.0	0.0
7	20	280	140	No	0	280	140	200.0	0.0
6	20	280	120	No	0	280	160	233.3	0.0
5	20	280	100	No	0	280	180	280.0	0.0
4	20	280	80	No	0	280	200	350.0	0.0
3	20	280	60	No	0	280	220	466.7	0.0
2	20	280	40	No	0	280	240	700.0	0.0
1	20	280	20	No	0	280	260	1400.0	0.0
0	0	280	N/A	No	0	N/A	N/A	N/A	N/A

Space Size (sq.ft.)................................ 280
Design Occupancy 14
Base Ventilation Rate Vb............................ 0
Per person Ventilation rate 20
DCV Desired?.................................... No
Activity Level (MET) 1

Air Change Effectiveness 1.0
AHU % OA 21.8
Outdoor Air CO_2 Level 350
Ventilation Design Airflow 1284
CO_2 Setpoint.................................. N/A
Location .... 3rd floor Conference Room

ASHRAE 62 WITH CO_2 DCV (TABLE 2)

Occupancy Level	R Vp	Sq.Ft.	DVR Vt	CO_2 Control	CO_2	Actual VT	+/- CFM	% Reg Vt	% Saving
14	20	280	280	Yes	280	280	0	100.0	0.0
13	20	280	260	Yes	260	260	0	100.0	7.1
12	20	280	240	Yes	240	240	0	100.0	14.3
11	20	280	220	Yes	220	220	0	100.0	21.4
10	20	280	200	Yes	200	200	0	100.0	28.6
9	20	280	180	Yes	180	180	0	100.0	35.7
8	20	280	160	Yes	160	160	0	100.0	42.9
7	20	280	140	Yes	140	140	0	100.0	50.0
6	20	280	120	Yes	120	120	0	100.0	57.1
5	20	280	100	Yes	100	100	0	100.0	64.3
4	20	280	80	Yes	80	80	0	100.0	71.4
3	20	280	60	Yes	60	60	0	100.0	78.6
2	20	280	40	Yes	40	40	0	100.0	85.7
1	20	280	20	Yes	20	20	0	100.0	92.9
0	20	280	N/A	No	0	N/A	N/A	N/A	N/A

Space Size (sq.ft.)................................ 280
Design Occupancy 14
Base Ventilation Rate Vb............................ 0
Per person Ventilation rate 20
DCV Desired?.................................... Yes
Activity Level (MET) 1

Air Change Effectiveness 1.0
AHU % OA 21.8
Outdoor Air CO_2 Level 350
Ventilation Design Airflow 1284
CO_2 Setpoint 770
Location .... 3rd floor Conference Room

WHERE: R Vp = Ventilation requirement in CFM/Person
Actual VT = Actual total Ventilation Supplied

DVRvt = Design Ventilation requirement
% Savings = CFM %

CARRIER CORPORATION

SYRACUSE, NEW YORK