HVAC - Guide to Demand Control Ventilation

An Online Continuing Education Course for Engineers

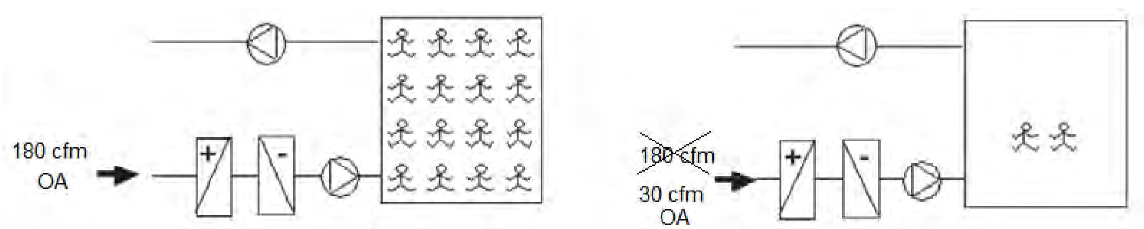
Course Number: HV-4019

Credit: 4 Hours / 4 PDH / 4 CPD

HVAC – Guide to Demand Control Ventilation

A. Bhatia, Mechanical Engineer

Most building codes require that a minimum amount of fresh air be provided to ensure adequate air quality. Typically, most ventilation systems set up the fresh air intake at fixed rate when they are installed, irrespective of the occupancy. This sometimes leads to poor indoor air quality (IAQ) and put penalty on energy consumption in cooling, heating and dehumidification. Good IAQ can be maintained when the fresh air supply rate responds to the load imposed by the number of people and by their activity in the room.



To make rational use of energy, the ventilation rate can be reduced when the spaces are only partially occupied. Demand-Controlled Ventilation (DCV) is a ventilation control strategy that provides automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy. DCV involves ventilating and conditioning the air precisely to meet our needs – no more and no less. The potential for savings is substantial, especially in premises such as offices, classrooms and hotel rooms where there is considerable variation between high and low during times when there are few or no occupants. DCV offers great potential for both new as well retrofit projects, but if improperly applied, it can create a negative building pressure leading to undesirable infiltration, building envelope degradation, and indoor air quality (IAQ) problems.

This course provides a necessary background to understand how the DCV operates and how it is applied under current codes and standards. The course is divided in 8 Sections:

SECTION -1: CO_2 and Indoor Air Quality

SECTION -2: Design Ventilation Rates

SECTION - 3: Outside Air Control

SECTION - 4: Applying DCV to HVAC Systems

SECTION - 5: The CO_2 Sensing Technology

SECTION - 6: Key Design Issues and Challenges

SECTION - 7: Investments and Energy Savings

SECTION - 8: Codes and Standards

SECTION 1: CO_2 and INDOOR AIR QUALITY

Ventilation is the process of bringing outside air into a building. Depending on weather conditions, ventilation air must usually be either heated, cooled, and/or be dehumidified. Because of this, ventilation air represents a significant portion of HVAC energy consumption. Maximum ventilation rates or the amount of fresh air in cubic feet per minute (cfm) that an air handler system brings into a building is provided in proportion to the maximum design occupancy of the building. In reality, the actual occupancy rarely approaches the maximum design occupancy and it is not unusual for an air handler to operate at the maximum ventilation rate continuously, even if the space is only partially occupied. This often results in over-ventilation... and that means higher-than-necessary energy costs.

Demand Controlled Ventilation (DCV)

Buildings do not require the induction of 100 percent fresh air all the time. As the number of people in a building varies at different times, so too should the demand for fresh air. The requirement for fresh air can be lower at the times of the day when fewer people are in a building. Demand Control Ventilation (DCV) is a method of introducing variable amounts of fresh air "on demand" based on actual occupancy patterns. The system provides a means to adjust the rate of ventilation continuously and automatically. Essentially, the control is achieved by means of a sensor (or a series of sensors) which respond to the variation in occupancy. Output from the sensor is applied to a control system (usually damper) that adjusts the rate of outdoor air flow through the ventilation system, thus ensuring that good air quality is continuously maintained. Three primary strategies are often used:

1. **Occupancy schedules:** supply design outdoor air during occupied hours as scheduled, with minimum or no outside air during unoccupied hours. Simple timers may be used to switch the ventilation system on or off at set times.

2. **Occupancy sensors:** supply design outdoor air during occupied times as sensed, with minimum or no outside air when zone is unoccupied. System may use proximity detectors and counters that can control the rate of ventilation according to the detection of occupancy and number of occupants in a space at any time.

3. **CO_2 sensors:** supply sufficient outdoor air to keep CO_2 concentration within bounds.

The first two strategies rely on estimates and approximations and do not necessarily yield guaranteed results. Still these strategies are significant improvements over supplying a fixed quantity of outdoor air. Most modern DCV systems use carbon dioxide (CO_2) sensors to continuously monitor the indoor CO_2 levels and provide real time feedback to regulate the amount of fresh air admitted for ventilation. The use of CO_2 sensors allows much better control over ventilation and is recognized valid by the most model building codes including ASHRAE Standards. The U.S. Green Building Council gives points in its Leadership in Energy and Environmental Design (LEED™) rating system for use of CO_2-based ventilation control in buildings.

Benefits of CO_2- Based DCV

During heating and cooling periods, energy is required to add or remove heat to fresh air introduced into a building. Over-ventilation is one of the largest indirect contributors to a building's energy use. The fact that a majority of Canadian and U.S. buildings deliver fresh air to the building's occupants at a fixed or constant volume represents the heart of the business case for Demand Controlled Ventilation (DCV). Compared to a fixed ventilation approach, DCV offers considerable advantages:

1. Excessive over-ventilation is avoided while still maintaining good Indoor Air Quality (IAQ) and providing the required cfm-per-person outside air requirement specified by codes and standards.

2. Saves energy by avoiding the heating, cooling, and dehumidification of more ventilation air than is needed.

3. Provides an opportunity to monitor both occupancy and ventilation rates in a building all the time.

4. Provides valuable information about occupancy trends, which can be useful for business analysis, operational & maintenance planning of equipment and ensuring safety in the premises.

5. In some buildings, infiltration air or open windows may be a significant source of outside air. A CO_2 sensor will consider the contribution of infiltration in a space and only require the mechanical system to make up what is necessary to meet required ventilation levels.

6. When integrated with the appropriate building control strategy, ventilation can be controlled zone by zone based on actual occupancy. This allows for the use of supply air from under-occupied zones to be redistributed to areas where more ventilation or cooling is needed.

7. A CO_2 control strategy can be issued to maintain any per-person ventilation rate. As a result, this approach is highly adaptable to changing building uses and any changes that may occur in future recommended ventilation rates.

According to the observations, the savings range from 5 to 80 percent depending on the application and ambient conditions. System paybacks from CO_2-based DCV will be greatest in higher density spaces, where occupancy constantly changes (e.g. schools, theaters, retail establishments, and meeting/conference areas).

CO_2 LEVELS & VENTILATION

People continuously exhale predictable quantities of CO_2 as they breathe. If the number of people in the space is doubled, the amount of CO_2 produced will double. Because CO_2 production is so consistent and predictable, it can be used as a reliable indicator of the air quality and ventilation rate. A high level of CO_2 in a room (>1000 ppm) indicates insufficient ventilation and a low level of <600 ppm may suggest that the ventilation rate could be turned down while maintaining a satisfactory IAQ with lower energy costs.

What is a good CO_2 level?

There is no single good value of CO_2 level. Many studies have been performed on human perception to establish the relationship between optimum CO_2 levels and occupant comfort and the studies show that a 20% dissatisfaction criterion corresponds to a CO_2 level of 1000 ppm. In other words, when the CO_2 level is above 1000 ppm, 20% of the people will find the air quality unacceptable.

ASHRAE Standard 62–2001, Section 6.1.3 states that comfort (odor) criteria is likely to be satisfied if the ventilation rate is so set that the 1,000 ppm of CO_2 is not exceeded. The absolute 1,000 ppm value was often interpreted as the *ceiling* CO_2 concentration for acceptable indoor air quality. But since, an indoor CO_2 measurement is a dynamic measure of the number of people in a space, it is not appropriate to go for absolute value of 1000 ppm. Rather it is much more logical to determine the cfm/person ventilation rates by measuring the indoor-outdoor CO_2 difference. The 2004 edition of ASHRAE 62 revised wording of Section 6.1.3 specifically to include 700 ppm difference between indoor and outdoor CO_2 concentrations as an acceptable level of human bio-effluents. This value is based on a specific ventilation rate (15 cfm/person), activity level (1.2 MET*) and outdoor CO_2 concentration of 300 ppm.

*The CO_2 generation from people is function of activity level. The term used to define the activity level is the "MET", which stands for "metabolic equivalent task". Higher the duration and intensity of physical activity, larger will be the oxygen consumption and larger will be the exhaled quantity of CO_2.

Important!

1. Carbon dioxide is not a contaminant in occupied spaces. This a major misconception of many that use CO_2 levels to reset the outside airflow rate. The table below shows various carbon dioxide thresholds and their descriptions.

CO_2 Level (ppm)	Description
90,000	NIOSH, lethal after 5 minutes
40,000	OSHA, immediate danger to life
30,000	OSHA, Safe for 10 minutes
5,000	OSHA, Safe for 8 hr/day – 40 hr week
1,000	Recommended indoor level (odor)
350 - 450	Average outside ambient level

It is important to note that the 1,000 ppm level is a recommendation and not a ceiling.

2. An elevated indoor CO_2 concentration is related to the occupants in the building, the building's ventilation rate, and the CO_2 level in the outside air.

3. Indoor CO_2 can accumulate if ventilation is not adequate to dilute and remove the CO_2 that is continuously generated by building occupants.

4. CO_2 measurement does not provide the count of people; it can be used only as an indicator of occupancy pattern and is only a measure of effective ventilation.

CO_2 differential and ventilation rates

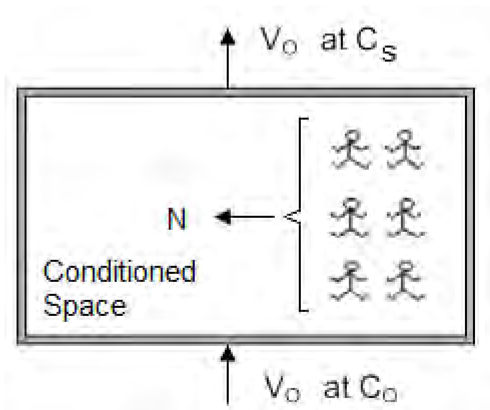
If the ventilation rate in an occupied space decreases, the carbon dioxide concentration will begin to increase and vice versa. Once people enter a room, CO_2 concentration will begin to increase. This level will continue to increase until the amount of CO_2 produced by the space occupants and the dilution air delivered to the space are in balance. Such a state is called the "equilibrium" point.

To understand how CO_2 sensors can be used to control ventilation, consider a conditioned space ventilated with outdoor air.

CO_2 enters the conditioned space in the ventilation air. The quantity of CO_2 in the ventilation air is the product of the outdoor air flow rate Vo and the concentration of CO_2 in the outside air Co.

CO_2 is generated in space from the occupants at a rate N.

CO_2 leaves the space in the exhaust air at concentration Cs.



A steady-state mass balanc... es:

Vo * Co + N = Vo * Cs

This relation can be re...

$$V_O = \frac{N}{(C_S - C_O)}$$

Where,

- V_o = outdoor airfl...
- C_s = CO_2 concentr...
- C_o = CO_2 concentra...
- N = CO_2 generatior...

The CO_2 emitted from a typ... light work "N" is about 0.0106 cfm/person corresponding to a typical activity level of 1.2 Met. If the maximum space concentration is to be held to 0.1 percent, 1000 ppm, and the outdoor concentration is 0.03 percent, 300 ppm, the minimum ventilation rate shall be:

$$V_O = \frac{0.0106}{(0.001 - 0.0003)}$$

Vo = 15.14 cfm per person

The example shows the CO_2 concentration in occupied space will not exceed 1000 ppm as long as 15.14 cfm per person of outdoor air with outdoor CO_2 concentration of 300 ppm is continuously being