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Maintaining Acceptable Air Quality in Office Buildings Through Ventilation

by C.Y. Shaw

Poor air quality in office buildings can result in loss of productivity, absenteeism and, in some cases, medical problems. The purpose of this Update is to provide guidelines for property managers and engineers for controlling indoor air quality using building ventilation systems.

The most frequently identified causes of poor indoor air quality that are directly related to building designs and operation, are air contaminants and inadequate ventilation. For office buildings, among the major air contamination sources are building materials and furnishings, occupants' activities, and office equipment. In some cases, air contaminants generated outdoors can be brought into a building by the ventilation system. To minimize some of these sources effectively and economically, designers, building owners and managers, and building engineers have been increasingly using preventive measures, such as specifying building materials and furnishings with low emission potentials, locating the outdoor-air intakes away from known outdoor sources, and using special exhaust systems to remove localized contamination sources.

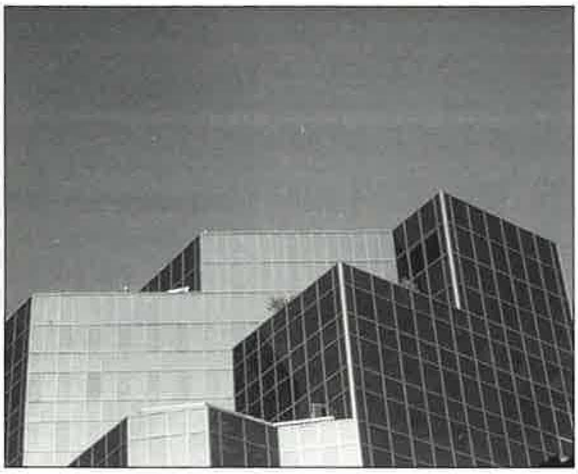

Figure 1. Typical high-rise office building in which the ventilation system plays a key role

However, many contaminants, such as those generated by occupants' activities, have to be reduced by building ventilation.

Acceptable Indoor Air Quality

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc. (ASHRAE) Standard 62-89 defines acceptable indoor air quality as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction." To achieve acceptable indoor air quality, the Standard recommends two procedures: the Ventilation Rate Procedure, specifying the quality and quantity of ventilation air for a space, and the Indoor Air Quality Procedure, requiring the control of all known contaminants to some specified acceptable levels within a space. Of the two procedures, the Ventilation Rate Procedure is most frequently used.

The Ventilation Rate Procedure prescribes ventilation rates for various spaces and the outdoor air quality acceptable for ventilation. It also specifies that the ventilation systems should be designed and installed to ensure that the ventilation air is delivered throughout the occupied zones and that they do not cause conditions that conflict with ASHRAE Standard 55-1992, Thermal Environmental

construction

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Figure 2. Achieving acceptable IAQ depends not only on the quantity of ventilation air but also on adequate distribution to individual workstations.

Conditions for Human Occupancy. For office buildings in North America, these requirements can usually be met by supplying 10 L/s of ventilation air per person into a building through outdoor-air intakes that are located away from any known outdoor contamination sources, such as a parking lot. The distribution of the appropriate amount of ventilation air to each occupied zone can be reasonably ascertained by ensuring that the CO_2 concentration in any workstation is 1000 ppm or less.

Ventilation Strategies

Once a building is occupied, ventilation is routinely used by building engineers to maintain the indoor air quality level. Ventilation is particularly effective in two situations:

- to re-establish the indoor air quality level after a scheduled shutdown of the (HVAC) system;
- to speed up the removal of contaminants in areas where renovations are taking place.

To use the ventilation strategy for these purposes efficiently and economically, it is not enough to simply increase the ventilation rate. The building engineer must know when, by how much and for how long the ventilation rate must be increased.

Two ventilation operation strategies are used to maintain acceptable air quality in offices: a normal mode and an enhanced mode. The normal ventilation mode is the operating mode used for day-to-day operations. The enhanced mode is the one used to control the initial off-gassing that occurs immediately after the installation of new materials that emit chemical gases.

Normal ventilation mode

The ventilation system in most office buildings is shut down during unoccupied hours as an energy-saving measure. The unoccupied period for a regular weekday lasts about 12 hours, for a regular weekend about 60 hours and for a long weekend about 84 hours.

The ventilation strategy required to deal with these conditions comprises two cycles: the flushing cycle, used before employees arrive at work, and the occupancy cycle, used while they are at work.

The flushing cycle

The concentration of contaminants generated by building materials, furnishings and equipment is generally maintained at an acceptable level by the HVAC system when it is operating. Once the ventilation system is turned off, however, the concentration of off-gassed chemicals increases. The flushing cycle is used to re-establish the quality of the indoor air to an acceptable level before the employees arrive in the morning. The ventilation rate used during the flushing cycle must be greater than that used during the occupancy cycle.

The outdoor air required for flushing varies from building to building and has to be determined experimentally. Based on experience acquired in managing public buildings, two air changes appear to be an appropriate starting value. This value must be adjusted based on the measured concentrations of CO_2 (i.e., ≤ 1000 ppm) and/or other key contaminants, such as volatile organic compounds, and the reaction of the occupants.

As the contaminant build-up is greater over a weekend and greater still over a long weekend shutdown, more air changes are required to reduce the concentration of contaminants to the same level achieved following a weekday shutdown. Thus, four and five changes of outdoor air are recommended as starting values following regular and long weekends, respectively.

The number of air changes required for a flushing cycle must be translated into a running time for the HVAC system. During spring and fall when it is feasible to use free cooling, the required number of air changes can be provided in a shorter time by using a higher ventilation rate. For example, if three is the number of air changes required for flushing, the operator can adjust the ventilation system to deliver

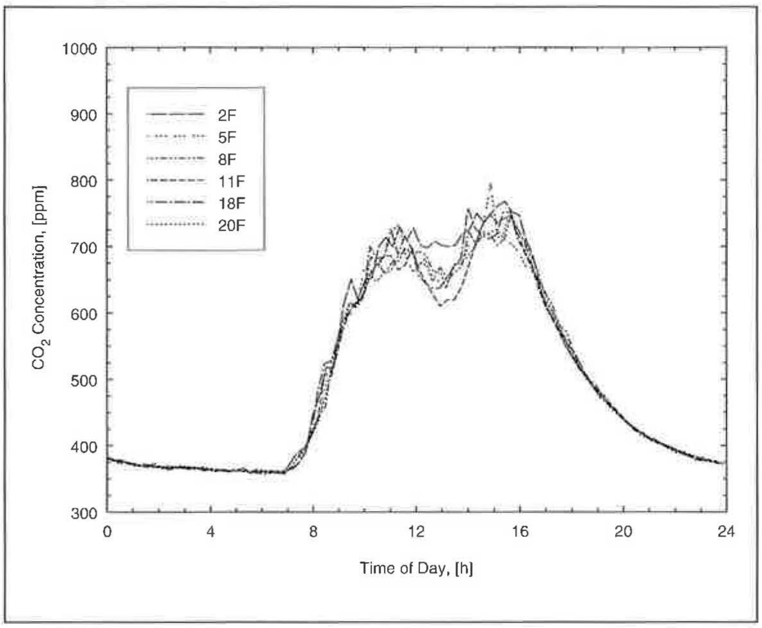

Figure 3. Typical CO_2 concentration profiles in occupied zones on six different floors of a 22-storey building

three air changes per hour for one hour, instead of one air change per hour for three hours. Based on the ventilation rate (i.e., air changes per hour), the starting time of the HVAC system can be determined.

During the heating season and on warm summer days, the amount of outside air that can be brought in during the flushing cycle depends on the heating or cooling capacity of the HVAC system.

The occupancy cycle

During the hours of normal occupancy, the ventilation rate must be adequate to maintain the minimum outdoor air supply of 10 L/s/person. As occupants produce CO_2, it is expected that the CO_2 concentrations in office buildings would be proportional to the number of occupants. One way to ensure that a building receives the appropriate amount of ventilation is to use a CO_2 ventilation demand controller that automatically adjusts the total outdoor air supply rate, according to the number of occupants in the building.

Two basic requirements must be met for a CO_2 ventilation demand controller to work properly:

- the CO_2 concentration should be relatively uniform throughout the building, and
- for the installation of the controller, a location must be found where the concentration of CO_2 is representative of concentrations throughout the building.

Figure 3 shows the daily CO_2 concentration profiles measured on various floors of a 22-storey office building with a constant amount of outdoor air being supplied by the HVAC system. It shows a rapid build-up of CO_2 starting around 7:30 a.m., a fairly high concentration during the day, and then a steady decrease starting around 4 p.m. The graph suggests that CO_2 generated by occupants distributed throughout the building will be reasonably well mixed in the indoor air very quickly. It is feasible to use the CO_2 concentrations to control the ventilation system. It is also expected that most office buildings with properly designed and commissioned all-air constant-volume HVAC systems would provide a similar degree of mixing between occupant-generated CO_2 and the indoor air, and would therefore be suitable for using CO_2 ventilation demand controllers.

Enhanced Ventilation Mode

The enhanced ventilation mode should be used only when part of a building is being renovated. It has two applications: the control of off-gassing and the control of contaminant migration.

Control of off-gassing

Some newly installed materials release contaminants at a high rate, but the rate decreases with time. The decay process reaches a steady rate of off-gassing within days or weeks of the installation of the material, depending on the type of material. During this period, additional ventilation is needed to dilute the large quantity of contaminants being released into the air.

Figure 4 shows the concentration profile (with background concentrations subtracted) measured in an office following the installation of a new carpet.

It is advisable during the renovation period to increase the ventilation rate to the full capacity of the building's HVAC system to dilute the contaminants. It is also advisable to suspend the practice of shutting down the ventilation system in the evening and on weekends.

Control of contaminant migration

Although most of the off-gassing products can be effectively removed from their place of origin (e.g., a renovated space) by operating the HVAC system in an enhanced ventilation mode, some of them may migrate through the building. In newly constructed buildings, their migration might not be

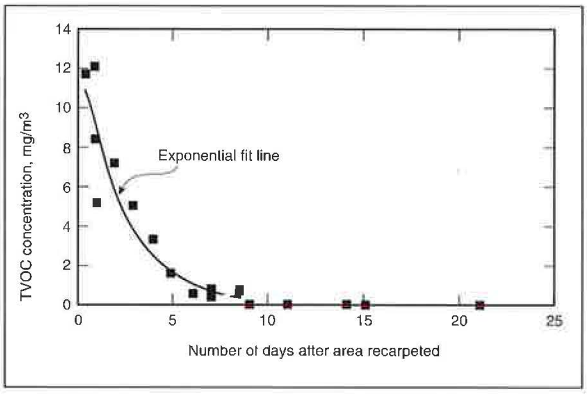

Figure 4. TVOC (total volatile organic compounds) concentrations in an office space with background concentrations subtracted, immediately following re-carpeting of the area (graph courtesy of Dr. G. Kerr, InAir Environmental Ltd.)

noticeable, since the off-gassing products are generated throughout the building. In existing buildings, the initial off-gassing is usually localized. Off-gassing products are typically generated where an old carpet is being removed, a new carpet laid, new furniture moved in, or walls painted. Even a minute amount of off-gassing products migrating through the building can be detected by the occupants. Therefore, precautionary measures should be taken to keep these contaminants from migrating from their place of origin to other occupied parts of the building.

To better understand this process of migration of off-gassing products through a building, computer programs have been used to predict how a contaminant spreads from the source to the surrounding areas under various weather conditions. These programs also assess the effectiveness of various ventilation strategies for removing contaminants — for example, venting through an open window or a vertical shaft. The results indicate that the most effective migration control can be achieved by sealing off the return-air grilles on the affected floor, while keeping the supply air coming into the affected floor and removing the air through a smoke shaft, a window opening or a stair shaft that opens directly to the outside. These means of control are effective, provided that the pressures induced by the stack effect and wind do not work against removal of the contaminants. For example, in winter, contaminants on lower floors will be pushed to upper levels because of the stack effect. The stack effect can be used to advantage by venting the contaminants through a vertical shaft directly open to the outside, e.g., a stair shaft. However, under windy conditions, venting the contaminants through a leeward window would be more effective.

Conclusion

By following the recommendations in this Update, it is possible to use the HVAC system to maintain acceptable air quality in an office building.

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