Air Purification to Reduce OA

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Buildings require ventilation with outdoor air to maintain a level of indoor air quality that provides a healthy environment for the occupants of the building interior space. In simple terms, carbon dioxide and bioeffluents are generated by building occupants while various gases and particulate matter (PM), some potentially harmful, are emitted by building materials and furnishings, equipment, and cleaning supplies, etc. By exhausting indoor air at an appropriate flow rate and replacing it with clean outdoor air, the concentrations of these occupant- and building material-generated gases can be maintained below objectionable or harmful levels.

ASHRAE Standard 62.1-2007 prescribes outdoor ventilation makeup airflow rates and methods to maintain acceptable indoor air quality in commercial and institutional buildings.[1] Underscoring the importance of maintaining a healthy indoor environment, Standard 62.1 has been adopted by most state and local building codes.

Outdoor ventilation air comes with an energy penalty, including the blower energy required to force outdoor air into the building and exhaust air out of the building, along with the energy needed to cool and dehumidify or heat the outdoor air to indoor comfort conditions.

Standard 62.1-2007 provides two alternate paths to provide adequate ventilation and acceptable indoor air quality.

- The **Ventilation Rate Procedure (VRP)** is a prescriptive approach with a table of minimum required outdoor airflow rates per occupant for a variety of commercial, institutional, and multifamily residential occupancies. The airflow rate per square foot of building floor area is based on the design occupancy density and the required flow rate per person, adjusted to reflect the air-distribution system used.
- The **Indoor Air Quality (IAQ) Procedure** provides a framework for an engineered approach to providing acceptable IAQ in a particular building. The building design team is responsible for identifying contaminants of concern, likely rates of generation of these contaminants, and acceptable levels of these contaminants; and defining a system and an outdoor ventilation rate that together will maintain contaminant concentration below the maximum acceptable concentrations. Air purification to remove some or all of the contaminants of concern can be part of the system enabling a reduction in ventilation airflow rates from the levels required by theVRP.

Air purification equipment and technology that can be used is described briefly in the following paragraphs.

Particulate matter cleansing can be achieved with mechanical filters, in which PM is removed from an airstream by capturing it on the filter medium; or electronic, electrostatic, or ionizing filters, in which particles are charged and precipitated out of the airstream. The efficiency of these filters can vary significantly and are generally rated for certain particle sizes at specific flow rates or face velocities. They generally have to be cleaned or replaced to avoid increased pressure drop and/or particle off-loading. PM filters have generally proven to be practical and are commonly installed in HVAC equipment.

Gas-phase adsorbent filters generally use physical adsorption to remove gas phase volatile organic compounds (VOCs) from an airstream. Adsorption occurs when gases bond to surfaces of solid materials via van der Waals forces. Granular activated carbon is the most common adsorption media. Sorbent filters become chemisorbent filters when coated with an agent (e.g., potassium or sodium permanganate) designed to react chemically with VOCs that are less easily physically adsorbed. Sorbent filters generally need to be integrated with fibrous PM filters because the sorbent media alone will typically not remove PM. Adsorbent filter media loses effectiveness and needs to be replaced or regenerated as the adsorption sites are filled with gas phase pollutants.

Photocatalytic oxidation (PCO) is an approach to gas-phase air cleaning that uses a monolith reactor coated with a photo-oxidative catalyst (e.g., titanium dioxide) that is irradiated with ultraviolet light. Simply stated, VOCs interact with the catalyst and the UV light, and the VOCs are broken down into carbon dioxide and water. PCO purification and PCO purification in combination with chemisorbents offer potentially high VOC conversion rates with low pressure drop.[2,3] However, they generally need to be combined with PM filters, and by some accounts, seem to be more costly than adsorbent VOC filters on both an installed and annual basis.[4]

Two other technologies can be used as alternatives to, or in combination with, air purification to reduce the energy impact of outdoor ventilation makeup air, energy recovery ventilation (ERV)[5] and demand-controlled ventilation (DCV),[6] both of which have been the subject of this column in previous editions of ASHRAE Journal. An ERV exchanges sensible heat and moisture from the incoming outdoor air to the conditioned air being exhausted from the building, reducing the cooling or heating required. It can be used with either Ventilation Rate Procedure, ventilation airflow rates or with reduced airflow rates in a system designed under the IAQ Procedure. DCV, which generally controls airflow as needed to maintain CO_2 (and/or other measureable pollutants) concentration below a maximum level, can be used by itself or in combination with air purification, depending on the generation rate of other contaminants. Buildings with large occupancy variations would tend to realize the most energy savings from DCV.

A final approach that could reduce the amount of outdoor air ventilation required by a building involves pollutant source control. Source control involves selecting building materials, office equipment, and cleaning supplies that have low emission of VOCs of concern.

Energy Savings Potential

The annual energy consumption in the U.S. associated with outdoor air ventilation in commercial buildings is on the order of 1.5 quads, accounting for both blower energy and the energy required to condition the exchanged air.[7] It is suggested that by using available purification technologies, the outdoor ventilation rate in many commercial buildings can be reduced by 50% from levels suggested by Standard 62.1, while still maintaining adequate indoor air quality.[8,9] This equates to an energy savings potential of approximately 0.75 quads of primary energy less the energy consumed by the purification systems, namely blowers required to overcome pressure drop.

Basic calculations based on general assumptions about purification requirements indicate that purification systems using sorbent and PM filters could consume 10% of the energy that outdoor air ventilation consumes.

Some retrofit air cleaning systems claim the pressure drop through the purification system is less than replaced HVAC PM filters. In these cases, any reduction in ventilation energy could be counted as savings.

Increased energy savings could be realized using the combination of air purification with DCV. Indoor air quality monitoring may be necessary for buildings relying on air purification to meet IAQ requirements because the contaminant removal effectiveness of adsorbents falls over time, and also because of liability concerns related to deviating from standard practices. If IAQ is monitored, controls can then be installed to vary the building or building zone ventilation as needed. If building ventilation equipment is sized to meet building needs at maximum occupancy, then many buildings could realize ventilation energy savings during periods when the building is not at maximum occupancy. Field experience indicates that actual occupancy levels are often 25% to 30% lower and as much as 60% to 75% lower in some buildings than design levels.[10]

Market Factors

The use of air purification equipment to reduce ventilation airflow involves a trade-off between the installed and operating costs of the purification equipment with any offsetting ventilation equipment cost reductions and energy savings.

In general terms, the energy cost of ventilation per unit flow rate of outdoor air is approximately \$1.50/cfm.[9,11] Based on anecdotal evidence and some costs of packaged ambient air purification system, and assuming a 50% reduction in outdoor air is possible, it seems reasonable that a payback period of less than three years is achievable. Also, if IAQ monitoring is necessary for the purification system, additional savings may be realized by using demand controlled ventilation.

Two other factors to consider in deciding whether to pursue air purification to reduce ventilation airflow rates are green building certification and the effort involved in implementing the IAQ procedure. The LEED® program of the U.S. Green Building Council is the most widely followed green building design certification program. As it currently stands, LEED points are awarded for *increasing* airflow by 30% above minimum requirements.

The IAQ Procedure places the onus for identifying contaminants of concern, likely rates of generation of these contaminants, and acceptable levels of these contaminants on the building design team. A certain amount of caution is in order when approaching these responsibilities. The science and technology of indoor air quality is complex.

Chapters 12 and 13 of the *2005 ASHRAE Handbook—Fundamentals*,[12] "Air Contaminants" and "Odors," respectively, provide an up-to-date distillation of the current technical knowledge base covering the indoor contaminants that ventilation with outdoor air is intended to mitigate. Together, these chapters cite approximately 200 references.

In Chapter 12, Table 5: "Major Chemical Families of Gaseous Air Pollutants (with examples)" identifies 27 families—six inorganic and 21 organic—of gaseous air pollutants, with between one and seven examples of each. Chapter 12 further defines eight categories of solid, liquid, and complex particulate contaminants. Figure 3 in Chapter 12 plots ranges of particle sizes (from 0.01 microns to 1000 microns) for almost 100 different particles found in indoor environments, ranging from dust to bioaerosols to pathogens.

Some examples of the full range of gaseous and particulate contaminants, some of which are not susceptible to removal by the air purification methods described previously, are: carbon dioxide, carbon monoxide, nitrogen oxides, radioactive gases (particularly radon), bioeffluents and bioaerosols, a range of chemical species that are emitted from building materials and furnishings, a range of chemical species that are emitted from office equipment and other equipment, and a range of chemical species that are emitted from cleaning supplies and other short-term vapor sources introduced into a given indoor space.

In the end, building design teams may conclude that ventilating with comparatively clean outdoor air is a relatively simple and effective way to dilute and exhaust a range of gaseous and particulate contaminants.

Air purification has been used successfully within the framework of the IAQ Procedure to reduce peak and average ventilation rates and save energy. Furthermore, there appears to be potential for considerable additional energy savings. One general category of applications where air purification can be particularly applicable are those situations where the outdoor air quality is poor and considerable particulate and gaseous contaminant removal is needed to make the outdoor air acceptable for indoor use.

References

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