Schnackel University

Schnackel engineers

ENHANCED HVAC INFECTION CONTROL: DILUTION VENTILATION

WHITE PAPER JULY 2020

Introduction

In our previous white papers on infection control through advanced HVAC strategies, we have focused on the *removal* of infectious particles from the airstream using various mechanical, photochemical or electronic means. This article will focus on the reduction of the *concentration* of infectious (and non-infectious) particles in the building through *dilution ventilation*.

The Ventilation Process

Ventilation is defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as "*the intentional introduction of air from the outdoors into a building*". The purpose of introducing outdoor air is, and has always been, to reduce the concentration of indoor air pollutants by diluting them with "clean" outdoor air.

When introducing outdoor air into a building, the same amount of air has to be removed from the building or the pressure inside the building will increase. As our founder, Dale Schnackel, used to say: "How much air can you blow into a Coke bottle without letting any air out?"

The excess air that results from the forced introduction of outdoor air is removed via the building's exhaust systems, relieved by the HVAC system through dampers, or relieved via exfiltration through leaks and cracks in the building envelope, or by any other path available, such as open doors and windows.

Since it is assumed that the "clean" outdoor air mixes with the "dirty" air inside the building before it is relieved, some amount of the indoor pollutants are removed as part of the air removed from the building, diluting the indoor contaminants. Clean air in, polluted air out is the basic concept. However, in order for this approach to work, the outdoor air must be cleaner than the indoor air, and there must be a good level of air mixing within the spaces. Our next white paper on *Ventilation Effectiveness* will address the mixing of air within the occupied spaces and the HVAC systems' ability to remove airborne contaminants from the space.

"Clean" Outdoor Air

The entire premise of dilution through outdoor air ventilation is dependent on the cleanliness of the outdoor air surrounding the building and specifically, at the point of entry via louvers or fans. When designing or modifying ventilation systems it is important to consider the location of the outdoor air intake. Any locations that have a potential for high levels of contaminants should be avoided, such as docks, alleys, streets and parking lots.

Also, any sources of contaminants from within the building or other buildings must be avoided. Most codes regulate the required distance from potential contaminate sources, requiring anywhere from 10' to 25' of minimum separation. However, even when following these minimum code requirements, consideration should be given to prevailing winds, parapets and anything else that might impact the flow of outdoor contaminants into the building air intakes.

Even with the best attention to the intake air locations, some geographic locations are still subject to very poor outdoor air quality, which could actually be worse than the conditions inside the building. Refer to the section titled *Outdoor Air Quality Monitoring* later in this white paper for considerations in locations that may have less than ideal outdoor air quality conditions.

Positive vs. Negative Building Pressure

Depending on the amount of resistance to the flow of air through the relief pathways, a positive, neutral or negative pressure can be created in a building as a result of the ventilation process.

Negative building pressure occurs when there are more exhaust pathways (exhaust fans) than there are supply pathways (outside air units) for air exchange with the outdoors. Negative building pressures are generally undesirable because they result in the uncontrolled flow of unconditioned infiltration air into the building through windows, doors and cracks in the building envelope. This uncontrolled flow can cause a multitude of heating, cooling and humidity control problems, as well as indoor air quality issues if the outdoor air has undesirable qualities including pollution, dust or odors.

Neutral building pressure occurs when the intake and exhaust pathways are perfectly balanced, with the quantity of incoming air matching the quantity of outgoing air exactly. Neutral building pressure is a highly desirable condition, however in practice it is nearly impossible to achieve. Normal variations in wind direction and speed, as well as thermal buoyancy pressures (stack effect) disrupt the building pressure balance on a constantly changing basis. As a result, a neutral pressure building constantly swings back and forth between negative and positive pressure depending on the whims of Mother Nature.

By keeping the amount of outside air introduced slightly above the total amount of relief and exhaust air, a building can be maintained in a positive pressure condition. It is generally accepted that a slight positive pressure in a building is the most desirable balancing condition. It reduces the flow of unconditioned infiltration air into the building, thereby maintaining control of *where* the outdoor air is drawn in, so that it can be monitored, filtered and conditioned appropriately at its source.

Regulations

National and local codes have minimum ventilation requirements based on the occupancy classification of the space and the number of occupants to be expected. In addition to the national and local codes, ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality provides recommended minimum ventilation rates for commercial buildings. Standard 62.1 excludes dwelling units in residential occupancies, laboratories that contain hazardous materials, smoking areas, and any patient care areas not specifically listed in the Standard. These specialty areas are covered in other codes and standards.

Sample Ventilation Codes and Standards

The ventilation rates specified in the applicable codes and standards should only be considered as *minimum* acceptable values; not what is necessary to maintain a clean, healthy environment within any particular space.

Indoor Air Quality Monitoring

Indoor air quality can be monitored by deploying sensors throughout the building. The most common method is the carbon dioxide (CO_2) sensor. Carbon dioxide level has been the traditional metric for maintaining indoor air quality for the last 20 years. This is because the occupant perceived quality of the indoor air has been linked to the number of people in the space and the amount of human respiration. By adjusting the outdoor air ventilation rate based on indoor CO_2 concentration, it has been the intent that the most offensive of the indoor contaminants, odorous bio-effluents (body odor), would be sufficiently removed by the introduction of the correct amount of "clean" outdoor air to keep CO_2 levels at acceptable values. ASHRAE has recommended indoor CO_2 concentrations be maintained at or below 1,000 ppm in schools and 800 ppm in offices, or no greater than 600 ppm higher than the outdoor ambient CO_2 level. (See chart below.)

Normal CO_2 Levels
The effects of CO_2 on adults at good health can be summarized to:

- normal outdoor level: *350 - 450 ppm*
- acceptable levels: < *600 ppm*
- complaints of stiffness and odors: *600 – 1,000 ppm*
- ASHRAE and OSHA standards: *1,000 ppm*
- general drowsiness: *1,000 – 2,500 ppm*
- adverse health effects may be expected: *2,500 – 5,000 ppm*
- maximum allowed concentration within a 8 hour working period: *5,000 – 10,000 ppm*
- maximum allowed concentration within a *15 minute* working period: *30,000 ppm*

Extreme and Dangerous CO_2 Levels

- slightly intoxicating, breathing and pulse rate increase, nausea: *30,000 – 40,000 ppm*
- above plus headaches and sight impairment: *50,000 ppm*
- unconscious, further exposure death: *100,000 ppm*

Engineering ToolBox, (2008). *Carbon Dioxide Concentration - Comfort Levels*.

While CO_2 is still considered a good metric for maintaining *minimum* outdoor air quantities, it is not sufficient to address the overall issue of indoor air quality. Other contaminants must also be addressed including carbon monoxide, particulate matter, VOCs, biological contaminants, humidity, among others. True control of indoor air quality should include monitoring of a spectrum of contaminants that all impact the quality of the air we breathe. While there are no commercially viable monitors for biological contaminants like SARS-CoV-2 in the air, a robust monitoring strategy of the other factors contributing to indoor air quality will help minimize the concentration of these pathogens, while improving the overall quality of the air in our buildings.

Air quality monitoring systems can be stand-alone or a part of the building management and control system. The obvious advantage of tying air quality monitoring systems into a building management system is that the ventilation systems can be automatically adjusted to react to the indoor air quality conditions and either improve the quality of the air or conserve energy when the air quality conditions are within acceptable range.

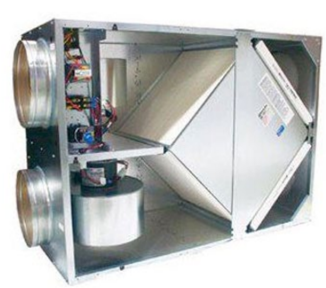
Outdoor Air Quality Monitoring

Densely packed urban areas such as New York City, or locations known for stagnant outdoor air conditions, like Los Angeles, Phoenix and Houston, can often have such poor outdoor air quality that, during certain periods, ventilation rates should be kept to a minimum to prevent making the air inside the building *more* toxic rather than *less* toxic through outdoor air ventilation. In some cases, ozone or other contaminate levels outside may preclude any increase in ventilation rates above code minimum levels.

Under these conditions, outdoor air quality monitoring systems should be coupled with indoor air quality monitoring systems to compare the quality of the airstreams and optimize the blend to achieve the best possible conditions for the building occupants. In these difficult locations, other means of "cleaning" the air become even more essential.

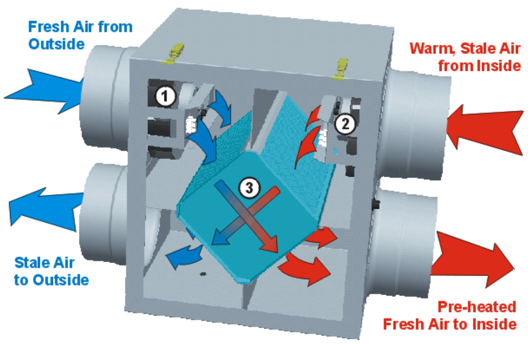
Energy Recovery

Except under the mildest of outdoor conditions, the introduction of outside air significantly adds to the overall energy use of a building. To mitigate the added energy load, the implementation of an energy recovery scheme should be considered. Air-To-Air recovery solutions may be stand-alone ventilators (Dedicated Outdoor Air Units) or an accessory to the main HVAC unit.




Energy Recovery Devices

These units efficiently transfer the heating or cooling "energy" contained in the exhausted air stream into the new incoming airstream to reduce the burden of the outside air on the building's HVAC systems and energy consumption.



Energy Recovery Device in Heating Mode

Summary

The advent of the SARS-CoV-2 pandemic has increased the importance of dilution ventilation in the fight against disease spread through airborne contaminants. Dilution ventilation can be a very effective means of reducing the concentration of SARS-CoV-2 in the indoor air, however it has some drawbacks that must be controlled. A general rule of thumb is that a pollutant's concentration is reduced by approximately 50 percent for each doubling of the ventilation rate. This makes dilution ventilation very effective at reducing the concentration of contaminants, including viruses, suspended in the building's air. This benefit, however, comes at a cost in terms of the energy consumption and environmental impact of the building. Any ventilation strategy that includes dilution ventilation above minimum code levels should mitigate the impacts on the environment by implementing an efficient and cost effective energy recovery system. With increased ventilation rates, these systems pay back their initial costs very quickly in most locations.

The addition of both indoor and outdoor air quality monitoring systems should definitely be considered in areas where the outdoor air quality can, at times, be worse than the indoor air quality. This is particularly important in locales known for high outdoor ozone levels. The best intentions of a dilution ventilation strategy can be quickly dashed by poor outdoor air quality, creating a more toxic rather than less toxic indoor environment.

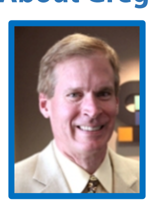
Therefore, the recommended ventilation rate for any space should be carefully determined based on many factors including the quality of the outdoor air, the overall filtration and air cleaning strategy for the building and the concern for energy consumption in the operation of the building. All of these factors must be balanced to determine the most appropriate ventilation strategy for any building.

Keep in mind that dilution ventilation only *reduces the concentration* of indoor contaminants once they are already suspended in the air, whereas removing the source of the contaminants is far more effective than any air dilution or air cleaning strategy. Our next white paper on *Ventilation Effectiveness* will address the overall effectiveness of the HVAC system in containing and removing airborne contaminants in buildings.

About Pedro:

Pedro Ferrer, P.E., has been involved in the design of mechanical systems for malls, mixed-use developments, corporate offices, national retail roll-outs, commercial and institutional buildings for over 26 years with Schnackel Engineers.

About Gregory:



Gregory Schnackel, P.E., LEED AP has been involved in the design of mechanical, electrical, plumbing, fire protections and information technology systems for malls, mixed-use developments, corporate offices, national retail roll-outs, schools, hospitals, medical facilities, commercial and institutional buildings for over 40 years with Schnackel Engineers.

RESOURCES	
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