Schnackel University

Schnackel engineers

ENHANCED HVAC INFECTION CONTROL: SCHOOLS

WHITE PAPER DECEMBER 2020

Introduction

Continuing our look into occupancy specific building types this paper examines the unique characteristics and challenges of mitigating the spread of airborne diseases in schools.

Our primary objective will be to answer the question:

> *What should I do to my school's HVAC systems to improve the safety and comfort of its occupants?*

We will review the common systems types found in schools and make recommendations for improving the infection control potential of these systems. We will also examine how well these systems can be adapted to meet the latest infection control standards and recommendations.

Agency Recommendations

The latest recommendations from the ASHRAE Epidemic Task Force for Commercial Buildings (updated 08/17/2020) include the following improvements related to any building's HVAC system:

- Maintain temperatures in accordance with ANSI/ASHRAE Standard 55-2017.
- Maintain relative humidity between 40% and 60%.
- Verify minimum ventilation requirements per Standard 62.1 are maintained. Increase ventilation rate as allowed per installed equipment and still maintain comfort levels.
- Operate systems at maximum outside air mode for two hours before and two hours after occupied times.
- Increase filter rating to MERV-13 if equipment can handle the additional pressure loss.

(https://www.ashrae.org/technical-resources/resources)

The Centers for Disease Control and Prevention's Resuming Business TOOLKIT includes the following general recommendations for all ventilation systems:

- Increase ventilation rates or percentage of outdoor air.
- Disable demand-controlled ventilation (DCV).
- Improve filtration to MERV-13.

(https://www.cdc.gov/coronavirus/2019-ncov/community/resuming-business-toolkit.html)

Typical School HVAC System Types

School facilities may be served by a wide variety of system types including, but not limited to, the following:

- Terminal units: Fan coil, WSHP, GSHP, VRF, split-systems.
- Central air handlers with terminal VAV boxes.
- Commercial packaged roof top units.

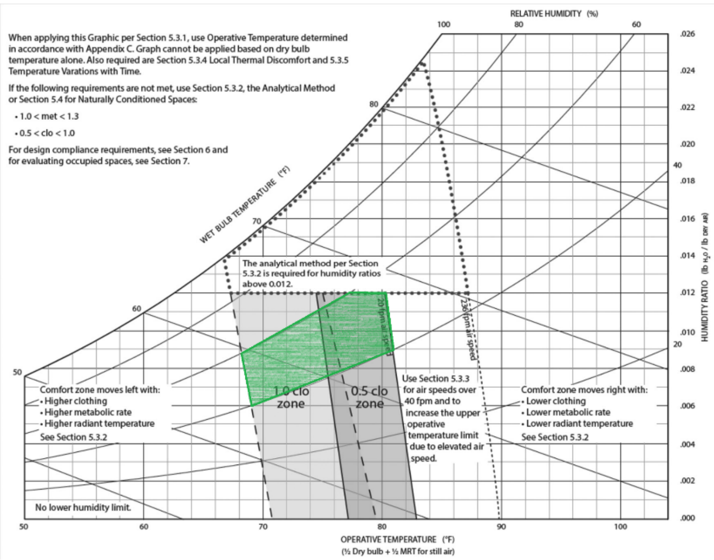
The central air handling systems (indoor modular, indoor self-contained and outdoor packaged types) handle the introduction of fresh outside air in the equipment itself, through various forms of dampers and intake hoods. The terminal unit systems are usually paired with a dedicated outside air system or are fitted with through wall louvers or gravity intake hoods to obtain fresh air directly.

Nearly all of the system types associated with school facilities offer many options for improving indoor air quality and reducing the risk of the spread of contaminants and pathogens. The key is selecting the right combination of measures to achieve the optimum result for each system, within the budget constraints of the project, while maintaining acceptable comfort levels for the occupants.

Temperature Control

ANSI/ASHRAE Standard 55-2017 does not directly specify temperature requirements for various occupancies. This is due to the fact that occupant comfort is a very subjective matter. Different individuals have different expectations with respect to temperature and humidity in order to determine if a space is considered "comfortable". In addition, the perceived comfort level is impacted by a multitude of factors including the metabolic rate of the activities in the space, the air temperature, the radiant temperature, the relative humidity, the clothing insulation levels of the occupants and the average airspeed in the occupied zone.

Instead of indicating a specific temperature range for each occupancy, ASHRAE 55 recommends that spaces be maintained within a band of coincident temperature and humidity levels, taking into account the velocity of air movement in the occupied zone, as indicated by the grey shaded area on the graph below.



ASHRAE 55: Acceptable Range of Operative Temperature and Humidity for Spaces

The green shaded area superimposes the recommended anti-viral humidity range of 40%-60% RH on the ASHRAE 55 comfort zone chart to achieve a PPD of <10% in a highly effective, anti-viral environment. As is evident from the graph, there is a fairly narrow range of coincident temperatures and humidity levels that are considered acceptable for both human comfort and for infection control. Any modifications to the HVAC systems should be carefully coordinated to ensure that the end result still lands within the green bounded area of human comfort and effective infection control.

Facilities personnel or qualified service contractors should verify that the temperature and humidity sensors in all areas are calibrated and operating properly, prior to embarking on an upgrade program to improve infection control.

Ventilation Systems

Based on the requirements of ANSI/ASHRAE Standard 62.1-2019, typical school occupancies should be receiving anywhere from 1.5 air changes to 3.0 air changes of outdoor air. Older facilities may be significantly higher or lower than these rates depending on the type of system, the level of maintenance, past energy conservation efforts and the tightness of the building.

While the ASHRAE 62.1 Standard meets minimum code requirements, some areas may not achieve the air change rate that is considered sufficient for the purpose of an effective dilution ventilation strategy for viral control. Most recent studies and the current CDC guidelines recommend a minimum of 2 to 4 air changes per hour of outdoor air to achieve a reasonable level of infectious agent dilution. See our white paper on Dilution Ventilation for further details.

Air changes per hour	Minutes required for removal efficiency 99%	99.9%
2	138	207
4	69	104
6	46	69
12	23	35
15	18	28
20	14	21
50	6	8
400	<1	1

Time required for infectious agent removal based on the number of air changes per hour (adapted from CDC guideline [28])

Infectious Agent Dilution Ventilation Performance

Depending on the HVAC system installed and the outdoor temperature/humidity conditions, typical school systems may or may not be able to achieve a 2 to 4 air change rate, while still maintaining acceptable indoor temperatures and humidity. Therefore, the goal should be to achieve the maximum outdoor air ventilation rate possible at any given time without overloading the HVAC's system ability to properly condition the air.

Demand Controlled Ventilation Systems
Some newer school buildings may be equipped with Demand Controlled Ventilation systems or DCV, which vary the amount of outdoor air introduced based on the measured CO_2 levels in the space or return air stream. These systems are design to adjust the outdoor air intake system to reflect the actual occupancy of the building at any given time, rather than simply bringing in a fixed amount of outdoor air to meet minimum code requirements. DCV systems were introduced primarily as an energy conservation measure to ensure that the central HVAC system was not bringing in any more outdoor air than was necessary to maintain acceptable indoor air quality levels, generally defined to be indicated by <1,000 ppm total CO_2 concentration or <600 ppm above the outdoor ambient CO_2 concentration level. (Outdoor air typically contains between 350 and 450 ppm CO_2.)

While the CDC has recommended *disabling* DCV systems, it is Schnackel Engineers' recommendation that they be maintained, and even installed if they are not already present, to help ensure that the maximum amount of outdoor air is being introduced during periods of high occupancy. However, in lieu of a typical pre-COVID-19 set point of 1,000 to 1,200 ppm total CO_2, these systems should be lowered to a 600 ppm maximum set point to effectively double the amount of fresh air delivery to the space when the building is heavily occupied. As a general rule of thumb, a doubling of the ventilation rate will cut the concentration of contaminants in the air by approximately 50%. The system can then scale back the fresh air delivery somewhat during periods of lower occupancy or high outdoor ambient conditions, without requiring any manual intervention in the control of the system.

Economizer Operation
During periods of economizer operation (mild weather conditions), outdoor air rates rise to as high 100% of the supply air quantity, providing excellent air change rates (>10 AC/hr), better indoor air quality and lower energy costs. Any system that is not already equipped with an air side economizer, should be analyzed to determine if it can be retrofitted for both energy conservation and viral control improvement reasons.

Dedicated Outdoor Air Systems
Terminal unit systems which rely on Dedicated Outdoor Air Systems (DOAS) may be more challenging when it comes to increasing the ventilation rate. DOAS units are typically designed to within a fairly narrow band of the code prescribed minimum outdoor air ventilation rates and therefore would require significant modifications or even unit replacement to achieve the higher ventilation rates necessary to achieve effective airborne pathogen dilution. Such modifications may or may not be possible without significant investment in replacement systems and ductwork.

Ventilation System Maintenance
All HVAC systems, regardless of type, should be checked to ensure that the ventilation rates delivered to the occupied spaces are as high as possible without compromising comfort levels or causing undue loading on the system equipment. All dampers, motors, controls and accessories associated with the ventilation systems should be checked to ensure they are working properly, and meeting at least the minimum code requirements, if not higher. This is particularly important for older facilities that may not be operating properly due to maintenance issues or overly aggressive energy conservation efforts.

Filtration

Our Filtration White Paper took an in-depth look at the available filtration technologies that can be applied to almost any HVAC system. Please refer to that white paper for more specific information about MERV ratings, filter efficiencies and the associated pressure drop considerations. The primary objective of increasing filtration with respect to infection control, is to install as high-efficiency of filters as is possible, subject to the static pressure limitations of the HVAC system.

Centralized Air Handling Equipment

Central air handling units and commercial packaged roof top units should be capable of overcoming the additional static pressure associated with the higher MERV ratings recommended for infection control. Whenever possible, install filters of a MERV-13 rating, or higher, to achieve maximum viral droplet capture. Sometimes increasing the MERV rating of the filters will require either no modifications to the HVAC equipment or minor changes to the belts, pulleys and possibly the supply fan motor, all of which can be accomplished at a relatively minor cost.

Terminal Unit Equipment

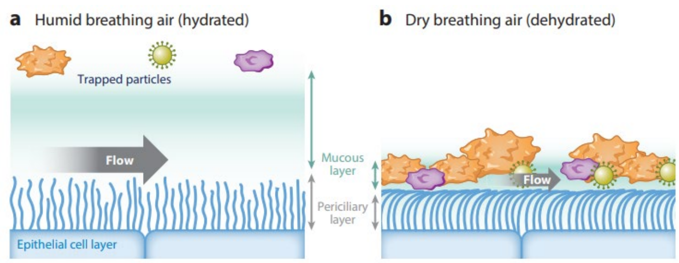
Terminal Unit systems can be more challenging when it comes to filtration. Since terminal units are relatively small in size and therefore have smaller fans and motors, most will not be capable of handling an upgrade to a MERV-13 rating. However, the filters should still be upgraded the highest MERV rating that each unit can safely handle. Even an upgrade to MERV-8 or MERV-10 can provide a meaningful reduction in the concentration of airborne infectious particles, particularly the larger droplets that are associated with SARS-CoV-2 spread. Each system should be evaluated by an HVAC design professional to determine the optimum replacement filter efficiency.

In-Room Filtration Equipment

In-room filtration systems may provide a viable option in older facilities equipped with small terminal units that are incapable of achieving the recommended filtration levels. These units should incorporate minimum MERV-13 or higher filters and preferably HEPA filters. In-room units should be sized to provide at least 6 air changes per hour (by volume) to significantly reduce the airborne contaminants levels. This means that in a space with well mixed air, the entire volume of air will be filtered once every 10 minutes. Using a HEPA filter (99.97% efficient on particles from 0.3 to 1.0 μm) in the in-room unit, this would reduce the number of particles initially in the air by 99% in 50 minutes.

Humidity Control

As we learned in our Humidity Control White Paper, maintaining the optimum humidity level of 40%-60% RH may be the single most effective way to mitigate the spread of viruses in buildings. This is due to both the human body's adverse reaction to low humidity and the viruses' ability to thrive and spread under low and high humidity conditions.



Mucociliary Clearance Mechanism

Most air conditioned school buildings have a reasonable capacity to dehumidify the air in the building using the air conditioning systems, however very few facilities are equipped with any type of humidification equipment to keep viral spread low during the critical winter months.

Humidification Mode

Central air handling units and commercial packaged roof top units should be fitted with central "clean-steam" humidification systems with in-duct steam distributors for each unit. Evaporative type humidifiers should be avoided unless they are coupled with UV light sterilization systems to ensure no mold or bacterial growth can occur.

Facilities served by terminal units will need to be evaluated on a case-by-case basis. Individual humidifiers featuring in-duct steam distribution might work in some instances. However, in most cases a different approach is warranted. Humidifiers with wall-mounted distributors or self-contained single room humidifiers are some of the options available for facilities without a viable means of installing central humidification.

Dehumidification Mode

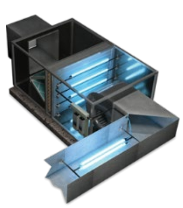
Schools whose operating schedule is primarily during the winter months, or do not have any air conditioning systems installed, can be less concerned about dehumidification, since the spread of respiratory viruses is typically reduced during the warmer months.

Most air conditioned school systems are able to operate efficiently under part-load conditions and maintain humidity levels within the target range during the summer months. Some of these systems may already be equipped with a dehumidification cycle option, utilizing either hot refrigerant gas or electric reheat to prevent over-cooling. If additional dehumidification is necessary, reheat coils can be added to the existing equipment to allow for drying of the air during light loading conditions. Dehumidification is as important as humidification to prevent the growth of mold and the propagation of viruses and bacteria in any facility.

Additional Prevention Measures

In addition to the recommendations discussed above, there are several other options available to provide additional layers of infection control and prevention. Often a multi-layered approach is the best strategy to bring a building up to its maximum infection control potential. These measures can include the following:

- In-Duct UV disinfection systems can be installed to disinfect the air as it passes through the HVAC unit and to keep the coils and drain pans free of any type of pathogen, including viruses, bacteria and mold.



- In large areas with high ceilings Upper Room GUV can be installed for added protection, killing the airborne viruses as they circulate within the rooms. These systems are extremely effective at killing airborne virus droplets and aerosols very near to their source. They can only be installed in areas where there is no possibility of human exposure to the UV radiation, generally above 7′-0″ above the floor.

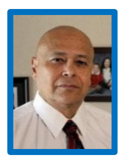
- Portable Decontamination Units can be used to powerfully disinfect classrooms and other areas in the event of a known infection case, or as a routine preventive measure on nights or weekends. These powerful remotely controlled units should only be used when the spaces are completely unoccupied and it is certain that no human exposure can occur, either from inside the building or through exterior windows that are not equipped with sufficient window coverings.

Portable Automatic GUV Device

Summary

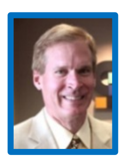
Schnackel Engineers can assist with a thorough evaluation of your facilities to ensure you are doing everything possible to prevent the spread of viruses, keeping both students and faculty safe. Please give us a call at 800-581-0963 or email us at info@schnackel.com for a consultation.

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. Email Pedro at pferrer@schnackel.com

About Greg:



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. Email Greg at gschnackel@schnackel.com

RESOURCES	
ASHRAE	https://www.ashrae.org/
Centers for Disease Control	https://www.cdc.gov/coronavirus/2019-nCoV/index.html
ASHRAE Journal	https://www.ashrae.org/technical-resources/ashrae-journal
Schnackel Engineers White Paper Series – Enhanced HVAC Infection Control.	http://www.schnackel.com/firm/white-papers/enhanced-hvac-infection-control-white-papers