Schnackel University

Schnackel engineers

ENHANCED HVAC INFECTION CONTROL: THEATERS

WHITE PAPER JANUARY 2021

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 theaters and places of assembly.

Our primary objective will be to answer the question:

> *What should I do to my facility to improve the safety and comfort of its occupants?*

We will review the common systems types found in these facilities 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.

Theaters and places of assembly (churches, concert venues, night clubs, etc.) are perhaps the hardest hit occupancies by the Covid-19 pandemic shutdowns due to their high occupant density and the very social nature of the events that take place in these facilities. They are also among the most difficult facilities to effectively control viral and biological disease spread through the HVAC systems, although there are many tested and emerging technologies that can be implemented to hasten their return to full occupancy and care-free operation.

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 HVAC System Types

Theaters and public assembly facilities may be served by a variety of primarily forced air system types including, but not limited to, the following:

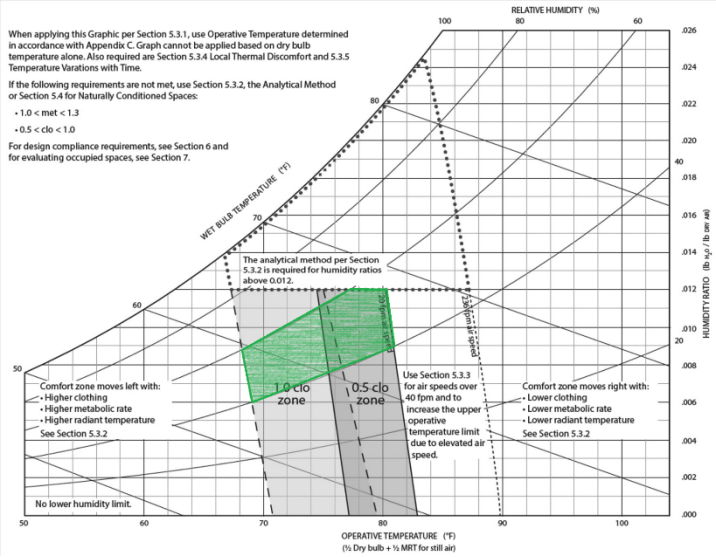
- Commercial Packaged Roof Top Units.
- Constant Volume Central Air Handlers.
- Variable Air Volume Systems

These systems handle the introduction of fresh outdoor air in the equipment itself, through various forms of dampers and intake hoods or louvers. Nearly all of these system types 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 predicted percentage of dissatisfied (PPD) rating of <10% in a highly effective, anti-viral environment. . 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

ANSI/ASHRAE Standard 62.1-2019 requires a minimum of 5 cfm per person plus 0.06 cfm per square foot of floor area of outdoor air for auditoriums and lobbies. Assuming a 25'-0" ceiling height and a typical occupant density, this translates into approximately 1.9 air changes per hour of outdoor air.

While these rates meet the minimum code requirements, the air change rates are not 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.

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])

Depending on the HVAC system installed and the outdoor temperature/humidity conditions, typical theater systems may or may not be able to achieve an increase in the ventilation rate to 2 to 4 air changes, 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. See our white paper on Dilution Ventilation for further details.

Demand Controlled Ventilation Systems

Some newer facilities 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, albeit to higher levels of ventilation that were previously recommended.

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.

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.

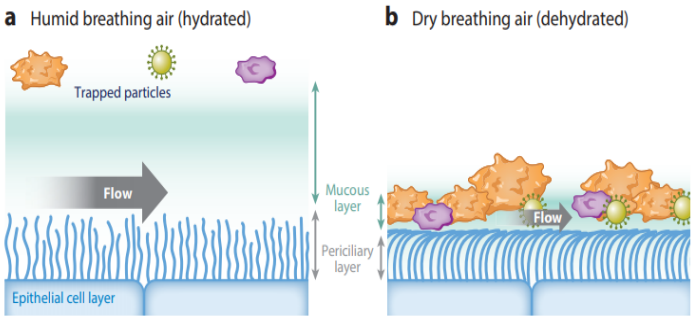
Filtration

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. Central air handling units and commercial packaged roof top units, whether constant volume or VAV design, 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.

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 facilities have the ability to dehumidify the air in the building using the air conditioning systems, however few facilities are equipped with any type of humidification equipment to keep viral spread low during the winter months.

Humidification Mode

Central air handling units and commercial packaged roof top units should be immediately 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.

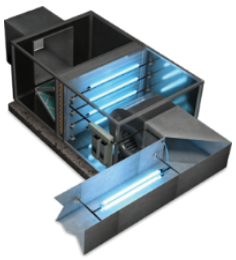
Dehumidification Mode

Most theater 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/hot water 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.

Germicidal Ultra Violet Sterilization

In addition to the recommendations discussed above, Germicidal UV Sterilization (GUV) is strongly recommended 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 public 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 and are not recommended in dark viewing rooms, like movie theaters and performance halls.

- Portable UV Decontamination Units can be used to powerfully disinfect auditoriums and other areas as a routine preventive measure during off hours. 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.

Portable Automatic GUV Device

Ionization

Air ionization systems are a promising new technology that have been effectively applied to several large public assembly facilities like the Staples Center in Los Angeles, California, for example. These systems operate on the principal of the ionization of the moving air molecules, usually at the HVAC equipment or in the ductwork, to both neutralize viral and biological contaminates and to agglomerate these and other particles so that they can be more easily removed by conventional filtration devices. The larger agglomerated particles are heavier and often precipitate out of the airstream, preventing further circulation to the facility.

Ionization air purification involves the use of a high voltage conductor (wire, plate, needle, etc.) to create air molecules with a negative (or positive) charge by adding (or removing) one electron to (or from) the air molecules, thereby creating N_2^- and O_2^- (or N_2^+ and O_2^+) molecules. These charged molecules (anions and cations respectively) attract impurities in the air by electrostatic attraction. Once they bond with the impurities in the air they are attracted to either positively charged surfaces (plates) in the device itself, or grounded surfaces in the nearby area like walls, floors and ducts.

Ionization equipment comes in two primary types: Bipolar ionization units, which incorporate large tubes of encapsulated ionization chambers and needlepoint ionization units, which utilize tiny fibers or "needles" that emit the corona discharge directly into the air stream.

The selection of the appropriate type of system is dependent on many factors including the availability of space in the HVAC equipment and the volume of air being treated.

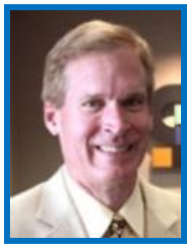
Summary

Schnackel Engineers can assist you with a thorough evaluation of your building to ensure you are doing everything possible to prevent the spread of viruses within your facility. 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