NEW YORK STATE OF OPPORTUNITY | NYSERDA

COVID-19 RESPONSE GUIDE

COLLEGES & UNIVERSITIES

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COVID-19 RESPONSE GUIDE FOR COLLEGES & UNIVERSITIES

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01
INTRODUCTION

PURPOSE OF THIS DOCUMENT

The COVID-19 pandemic has resulted in a significant health crisis and severe economic dislocation. Similar to other business sectors, higher education has experienced significant challenges managing the mission of educating students, while maintaining a safe indoor environment.

NYSERDA, with the assistance of Guth DeConzo Consulting Engineers, has developed this COVID-19 response guide to provide colleges and universities an actionable plan for addressing these challenges in a systematic manner, with regards to their existing HVAC systems. The document presents streamlined guidance, based on the *American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Building Readiness Guide* and *Schools and Universities Guide*, to enable higher education facility personnel to assess and upgrade HVAC systems for improved indoor air quality (IAQ) and infectious disease control or to identify professionals who can assist, where needed. IAQ is the condition and quality of the indoor air environment with regards to occupant health and comfort and is affected by the HVAC systems in place.

It must be emphasized that at this time, there is no single panacea or “silver bullet” for completely destroying viruses and other pathogenic microbes. All of the tactics and technologies need to be seen as useful tools, which if designed, constructed, and commissioned correctly can aid in the reduction of the impacts of COVID-19 and other viral and bacterial diseases.

THE REMAINING SECTIONS OF THIS GUIDE WILL ADDRESS THE FOLLOWING:

02
IAQ FUNDAMENTALS

Key indoor air quality (IAQ) variables that affect the risk of COVID-19 transmission.

LEARN MORE

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Roles that members of the academic community can play to support the IAQ Action Plan

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SYSTEMS EVALUTION CHECKLISTS

System-by-system guide to evaluating existing HVAC system conditions and the potential for system modifications to incorporate ASHRAE’s epidemic HVAC mitigation strategies

LEARN MORE

02

SECTION TWO

IAQ FUNDAMENTALS

02
IAQ FUNDAMENTALS

CRISIS MANAGEMENT

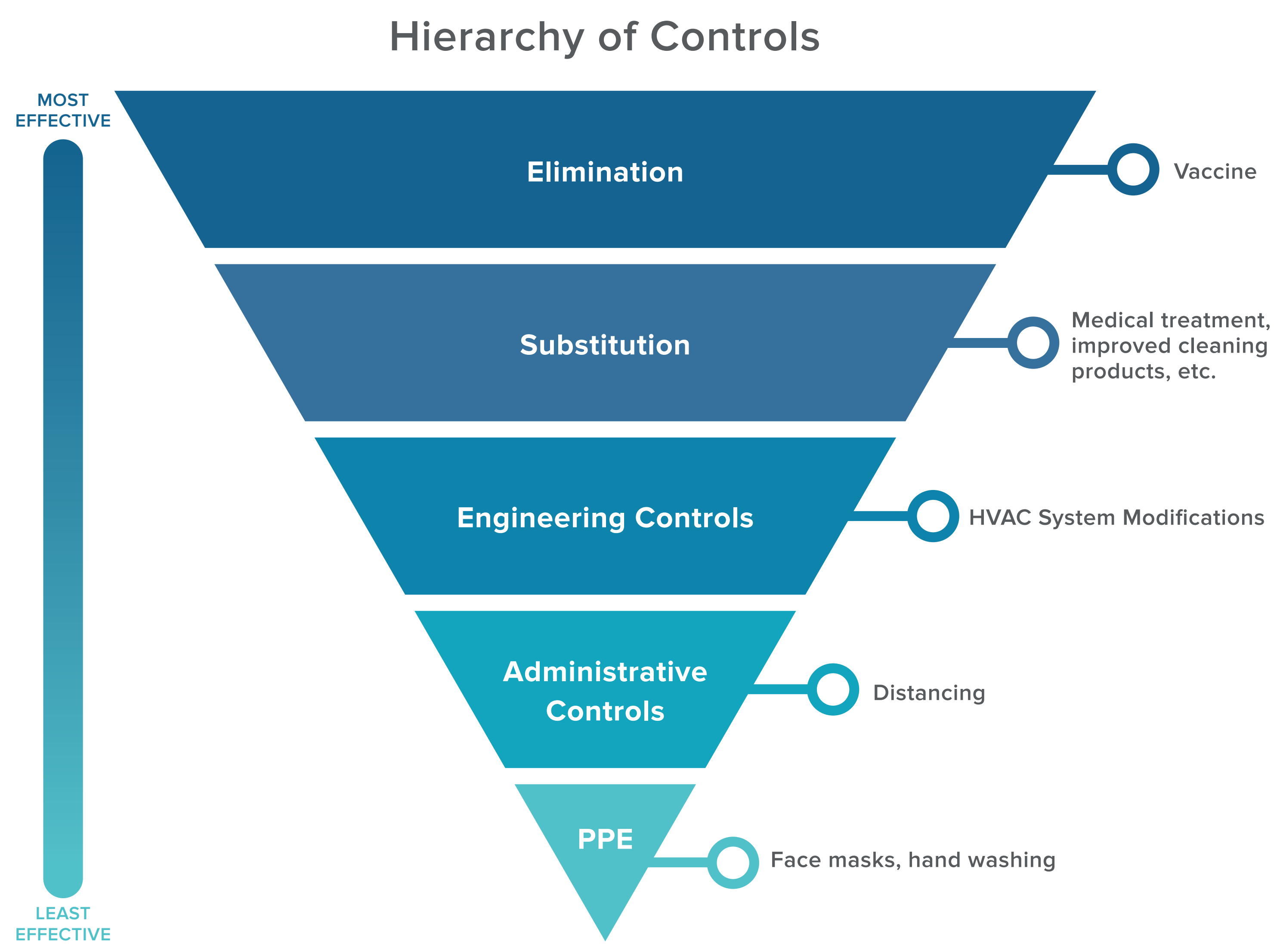
The National Institute for Occupational Safety and Health (NIOSH) has developed a "Hierarchy of Controls" (see chart on right) as a strategy to implement effective control solutions when faced with occupational hazards. The effectiveness scale of the solutions presented is based on longer-term occupancy periods. For short-term occupancy, PPE and distancing may be more effective solutions.

This document will focus on the engineering controls that can be taken in the here and now, which will both reduce the impact of the current COVID-19 pandemic and help to prepare for future IAQ issues for years to come.

ASHRAE has created a specific type of building operation under which facilities should operate during this current pandemic, termed Epidemic Conditions in Place (ECiP). The ECiP mode of operation is applicable to buildings with the following conditions:

- Occupied—at pre-epidemic capacity or reduced capacity
- Unoccupied temporarily
- Indefinite building closure

TRADITIONAL HIERARCHY OF CONTROLS



02
IAQ FUNDAMENTALS

HOW VIRUSES SPREAD INDOORS

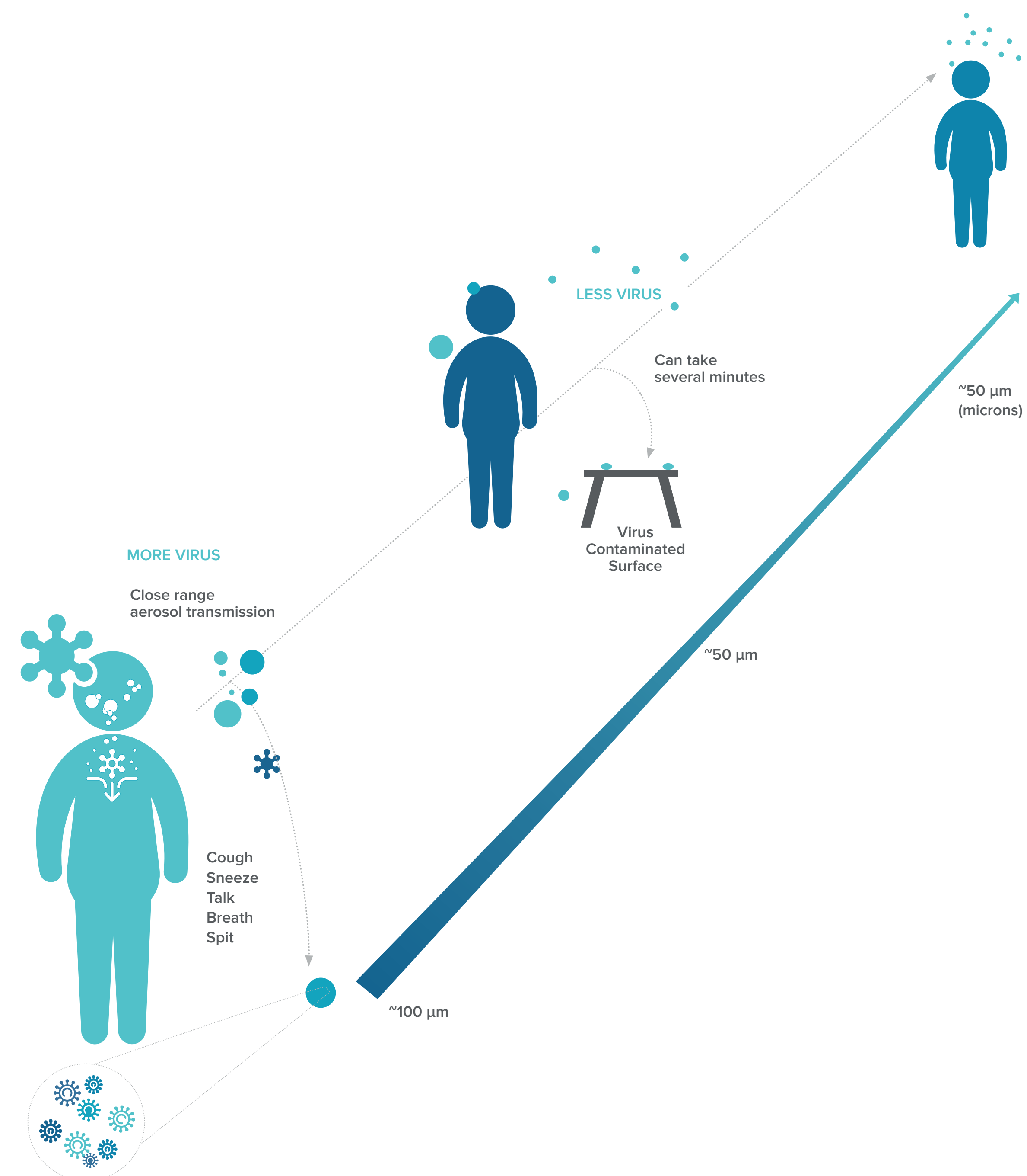
DROPLETS AND AEROSOLS
Aerosols are small particles and droplets that can move through the air. The infection control community historically has categorized aerosols as having the ability to travel farther before settling out of the air than droplets. However, even large droplets that are 50-100 microns can travel significant distances when there are strong drafts in a space. Droplets and aerosols containing infectious diseases are typically generated by coughing, sneezing, talking, singing, and breathing and are primarily spread in one of two ways: airborne dissemination or fomite contact.

AIRBORNE DISSEMINATION
Airborne dissemination occurs when infectious aerosols and droplets are spread through the air. Smaller aerosols, those less than 10 µm, can remain in the air for hours, or even days, and can travel much further distances infecting secondary hosts that had no contact with the primary host. The diagram on the following page identifies the factors that contribute to how viruses can spread.

FOMITE CONTACT
Fomites are intermediate objects or materials in disease transmission, such as door handles, plumbing fixtures, phones, remote controls, or other objects frequently used by multiple people. Due to gravity, infectious droplets quickly fall to the ground or surfaces within 3-7 ft, where they can attach to fomites. The droplets can sometimes be ejected back into the air by such actions as air movement, walking, etc. Once an object becomes contaminated, infectious agents can remain for hours or even days depending on the type of material.

Disease transmission by fomite contact cannot be easily mitigated by building heating, ventilation, and air-conditioning (HVAC) systems. Active in-space disinfection systems, such as ultraviolet germicidal irradiation (UVGI) units, can mitigate fomites if applied properly, but may have other concerns such as occupant safety or compatibility of materials.

AEROSOL SPREAD WITHIN THE LIVING ENVIRONMENT



02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION

As with any pathogen, certain conditions need to be present in order for the pathogen itself to successfully propagate. Virtually all 'super-spreader' incidents have involved various levels of "virus friendly" propagation conditions. The figure on the right summarizes the factors that significantly influence SARS-CoV-2's spread in the indoor environment.

NOTES (Fillable):

INDOOR AIR ENVIRONMENT FOR SPREAD OF SARS-CoV-2

Conditions for COVID-19 to Spread

02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

OUTDOOR AIR VENTILATION

There should be no surprise that the preponderance of COVID-19 cases is due to indoor air environments. While outdoor air exchanges are typically on the order of over 1,000 air changes per hour (ACH)[1], depending on wind-speed and physical constraints, we typically experience lower air exchange rates indoors.

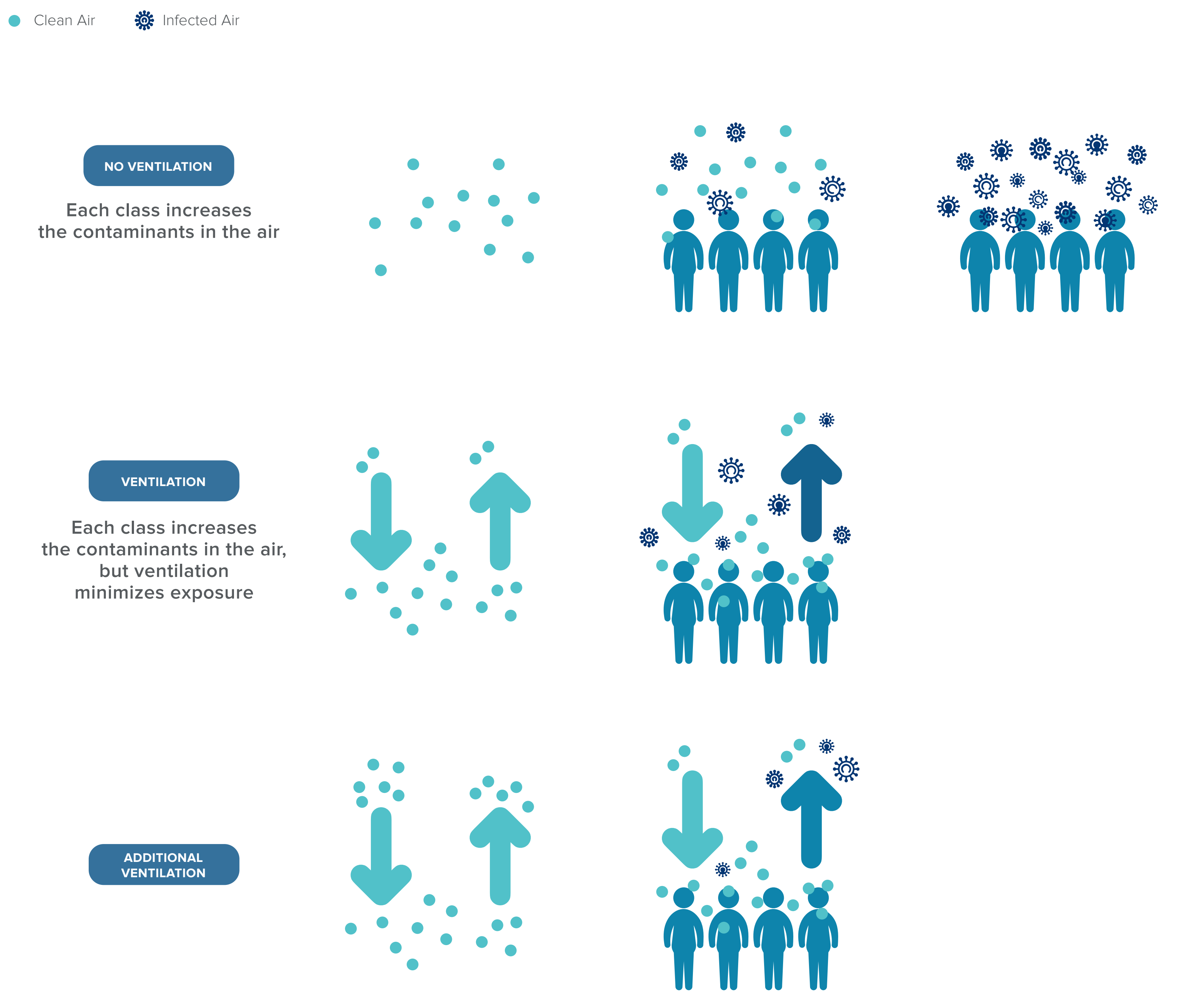
While most buildings are typically designed with 1 to 10 ACH, depending on activity, we normally benefit from much larger air volumes outside.

ASHRAE, a cognizant technical society providing HVAC system design standards and guidance, has documented that a lack of fresh air ventilation will allow concentrations of exhaled contaminants in aerosol form (think SARS-CoV-2 laden aerosols) to increase to higher levels, thus increasing the risk of infection to occupants.

As the top illustration on the right indicates, for a room with no outdoor air ventilation, the concentration of infectious particles (represented by the dark blue Infected Air graphics) will increase over time if the space is occupied by infected individuals. With the introduction of outdoor air ventilation (middle graphic), the concentration of infectious particles will increase, but not as quickly as the "no outdoor air ventilation" case. With increasing levels of outdoor air ventilation (bottom graphic), the concentration of infectious particles decreases even more, creating a safer space for inhabitants.

[1]Students and staff should be cautioned that just because one is outdoors doesn't mean there is good ventilation. Courtyards, awnings, half walls, etc. are just a few examples of areas where ventilation air can be compromised outdoors. As always, understand your surroundings so good decisions can be made.

CLASSROOM AND VENTILATION METAPHOR



02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

ASHRAE Standard 62.1-2019 (Ventilation for Acceptable Indoor Air Quality) establishes the minimum amount of ventilation air for a space/building as a function of space usage, number of occupants and space size.

The table to the right indicates the minimum outdoor air changes as recommended by the *ASHRAE Standard 62.1—2016* Ventilation Rate Procedure for typical higher education spaces (assuming 10 ft. ceiling height). At all times, including during epidemic scenarios, ASHRAE recommends achieving at least the minimum ACH for spaces per Standard 62.1.

While ventilation standards are based on years of research, best practices, and collective wisdom of previous standards, too often the actual amount of ventilation air in buildings falls short of standard. Some of the most common issues that can result in a shortfall in ventilation, discussed further in *Section 3*, are:

CHANGE IN FACILITY USE OR OCCUPANCY
Ventilation air rates are established at initial building design based on intended building use. Modifying the space use can affect the amount of ventilation air required, potentially making the existing system less than adequate.

ISSUES WITH AIR HANDLING UNITS (AHU)
It is common for issues to arise with AHU dampers, actuators, blades and linkages, sequences of operation, sensors, loose belts, and overloaded filters in addition to the presence of design, installation and balancing related issues. Frequently, units with economizers will have minimum and maximum damper positions set to align with outdoor air or return air percentages, while these positions may have no actual impact on air percentages.

ISSUES WITH DUCTWORK
Over time, ducts will experience failures, typically at the duct seams and/or access doors, that can create air leakage. As the amount of air leakage increases the delivered air volume is reduced.

[2]Source ASHRAE 62.1, 2016 table 6.2.2.2.1

TYPICAL MINIMUM AIR EXCHANGE RATES-OUTDOOR AIR[2]

Occupancy Category	People Outdoor Air Rate cfm / person	Area Outdoor Air Rate cfm / ft^2	Default Maximum Occupant Density # / 1000 ft^2	Outdoor Air Changes* (ACH) Assuming 10ft Ceiling*
Educational Facilities				
Classrooms	10	0.12	35	2.8
Lecture Classroom	7.5	0.06	65	3.5
Lecture Hall	7.5	0.06	150	7.5
Art Classroom	10	0.18	20	2.5
Laboratories	10	0.18	25	3.0
Computer Lab	10	0.12	25	2.5
Music / Theater / Dance	10	0.06	35	2.5
Multiuse Assembly	7.5	0.06	100	5.0
Corridors	0	0.06	0	0.5
Office Space / Food & Beverage				
Main Entry Lobbies	5	0.06	10	1.0
Break Rooms	5	0.12	50	2.5
Conference / Meeting	5	0.06	50	2.0
Office Space	5	0.06	5	1.0
Reception Areas	5	0.06	30	2.5

**Changes assuming typical occupant density and 10ft ceiling. For spaces that don't meet these requirements the Outdoor Air Changes must be calculated according to ASHRAE 62.1.*

02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

Issues with ventilation air are inevitable as systems age. By correcting deficiencies, ongoing commissioning, trending and tracking, steps can be taken to track airflow to ensure that sufficient minimum air flow is provided.

NOTES (Fillable):

[2]Source ASHRAE 62.1, table 6.2.2.2.1

TYPICAL MINIMUM AIR EXCHANGE RATES-OUTDOOR AIR[2] (CONT.)

Occupancy Category	People Outdoor Air Rate cfm / person	Area Outdoor Air Rate cfm / ft^2	Default Maximum Occupant Density # / 1000 ft^2	Outdoor Air Changes* (ACH) Assuming 10ft Ceiling*
Dormitories				
Barracks / Sleeping Area	5	0.06	20	1.0
Laundry Rooms, Central	5	0.12	20	1.5
Lobbies (Pre-function)	7.5	0.06	30	2.0
Multipurpose Assembly	5	0.06	120	4.0
Food & Beverage Services				
Cafeteria / Dining (Fast Food Dining)	7.5	0.18	100	6.0
Cooking	7.5	0.12	20	2.0
Public Assembly Spaces				
Auditorium Seating Area	5	0.06	150	5.0
Libraries	5	0.12	10	1.5
Lobbies	5	0.06	150	5.0
Museums / Galleries	7.5	0.06	40	2.5
Sports & Entertainment				
Gym, Sports Arena	20	0.18	7	2.0
Spectator Areas	7.5	0.06	150	7.5
Swimming (Pool & Deck Area)	0	0.48	0	3.0
Health Club / Aerobics Room	20	0.06	40	5.5
Stages, Studios	10	0.06	70	5.0
Health Club / Weight Rooms	20	0.06	10	2.0

**Changes assuming typical occupant density and 10ft ceiling. For spaces that don't meet these requirements the Outdoor Air Changes must be calculated according to ASHRAE 62.1.*

02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

RECIRCULATED AIR

For typical buildings, air that is supplied to conditioned spaces is typically a mixture of outdoor air and recirculated air. Using minimum outdoor air levels per *ASHRAE 62.1 2016* and filtered or cleaned, recirculated air minimizes the need to condition large amounts of outdoor air, which is energy intensive.

Role of Mechanical Filters

Proper installation and maintenance of filters can ensure that filters are working as efficiently as possible. Loose or mis-aligned filters, gaps in sealing or frames, bent or damaged filters can drastically affect the filter's ability to effectively clean the air.

Mechanical filters are the most common types of filters found in HVAC systems. Mechanical filters consist of media with porous fibers or stretched membrane material to capture particles and contaminants. Filters range in size, but the typical depths of filters are 1," 2," 4" and 12-15." Some filters have a static electrical charge applied to the media to increase particle removal, which can decrease over time. Minimum Efficiency Reporting Value-A (MERV-A) ratings reflect filter performance based on testing that disables the static electric charge. Consider this to understand the performance of these filters if the charge has been removed or dissipated.

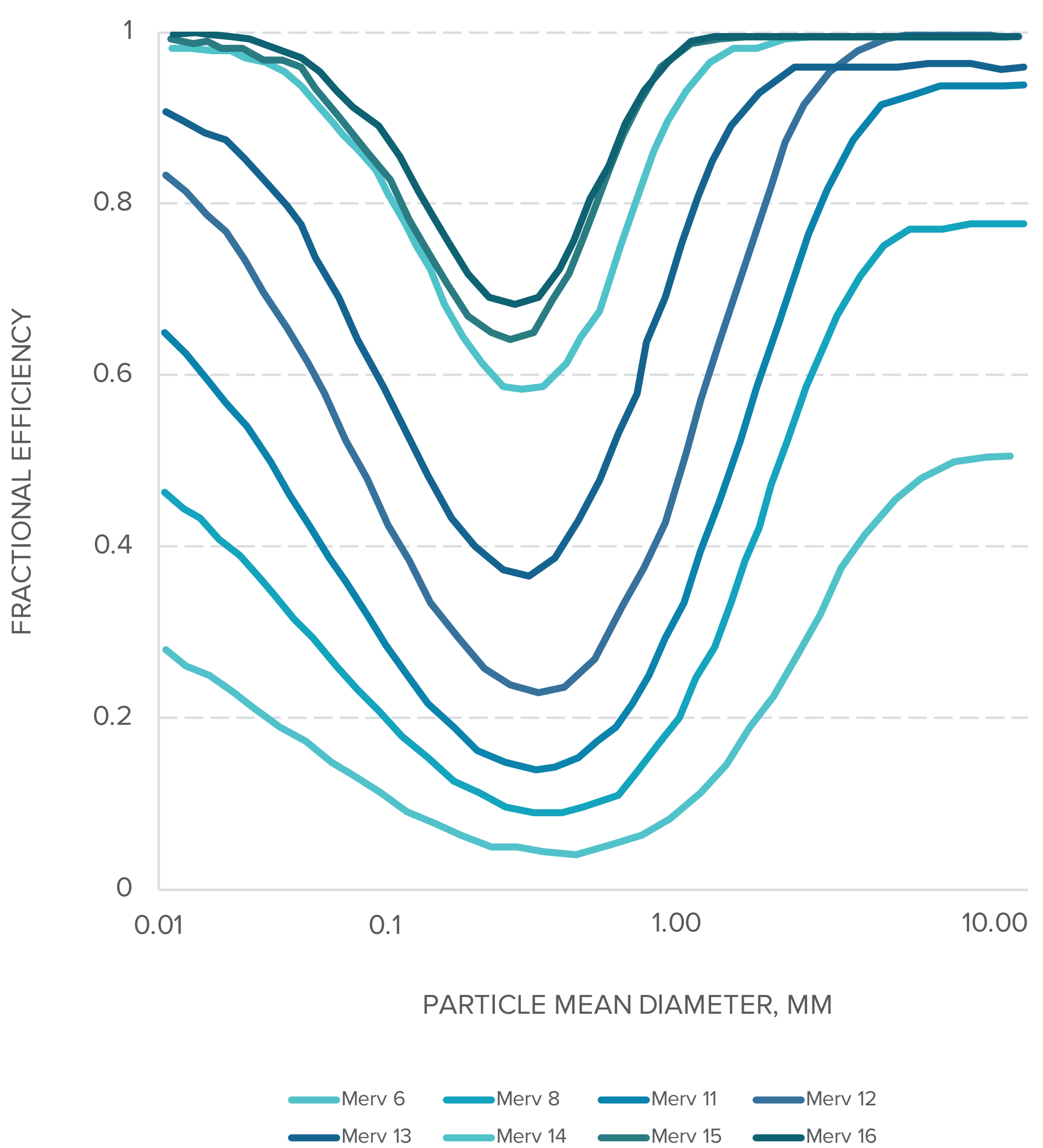
Filter performance is described by the MERV rating, which varies from MERV-1 to MERV-16.[3] The higher the MERV number the better the ability of a filter to remove particles from the air ranging in sizes from 0.3 micron diameter up to 10 microns in diameter at standard airflow conditions and face velocities specified in the test standard.

The efficiency of various MERV filters is depicted on the chart to the right, with, 0.3 µm particles the most penetrating (notice efficiency is lowest at this level).

Per ASHRAE, MERV-13 or higher filters are an effective balance of cost (installation and operation) versus protection. When increasing the MERV filtration rating, the pressure drop may increase depending on the existing and new filter selections, which can result in increased energy usage and/or airflow reduction.

[3]See *ASHRAE Schools and Universities guidance document (10-07-2020)*— "Filtration Upgrades," approximately page 23 and *ASHRAE Standard 52.2* for MERV ratings/filter performance. Filter efficiency chart sourced from Kowalski/Bahnfleth .

MERV FILTER EFFICIENCY CHART (AS FUNCTION OF PARTICLE SIZE)



02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

AIRFLOW PATTERNS

Beyond providing a reasonable amount of ventilation to space, it is important that the air be delivered and moved through space in such a way to effectively flush contaminants, and move air away from the breathing zone. If supply diffusers are too close to return or exhaust grilles, air may provide no contaminant removal benefit to a large part of the room. Facilities may not have the ability to modify current buildings' distribution ductwork. However, there may be instances where minor changes are possible; moving diffusers that are equipped with flexible duct to different areas within a suspended ceiling system.

Strong or turbulent air flow patterns can blow droplets over longer distances, potentially exposing some room occupants to more contaminants than if air moved slowly through a space. Furniture, partitions and equipment may cause 'dead zones' of stagnant air that can reduce air flow, thus trapping contaminants in one place for long periods of time. It is imperative to consider air flow patterns when determining the quality of the indoor air in a space. This is discussed further in *Section 4*.

In the absence of required directional airflow, good air mixing should be the target and there should not be any strong air currents that can increase direct transmission from one person to others. There is currently no guidance issued by ASHRAE for space airflow. Multiple organizations are working on sufficient recommendations.

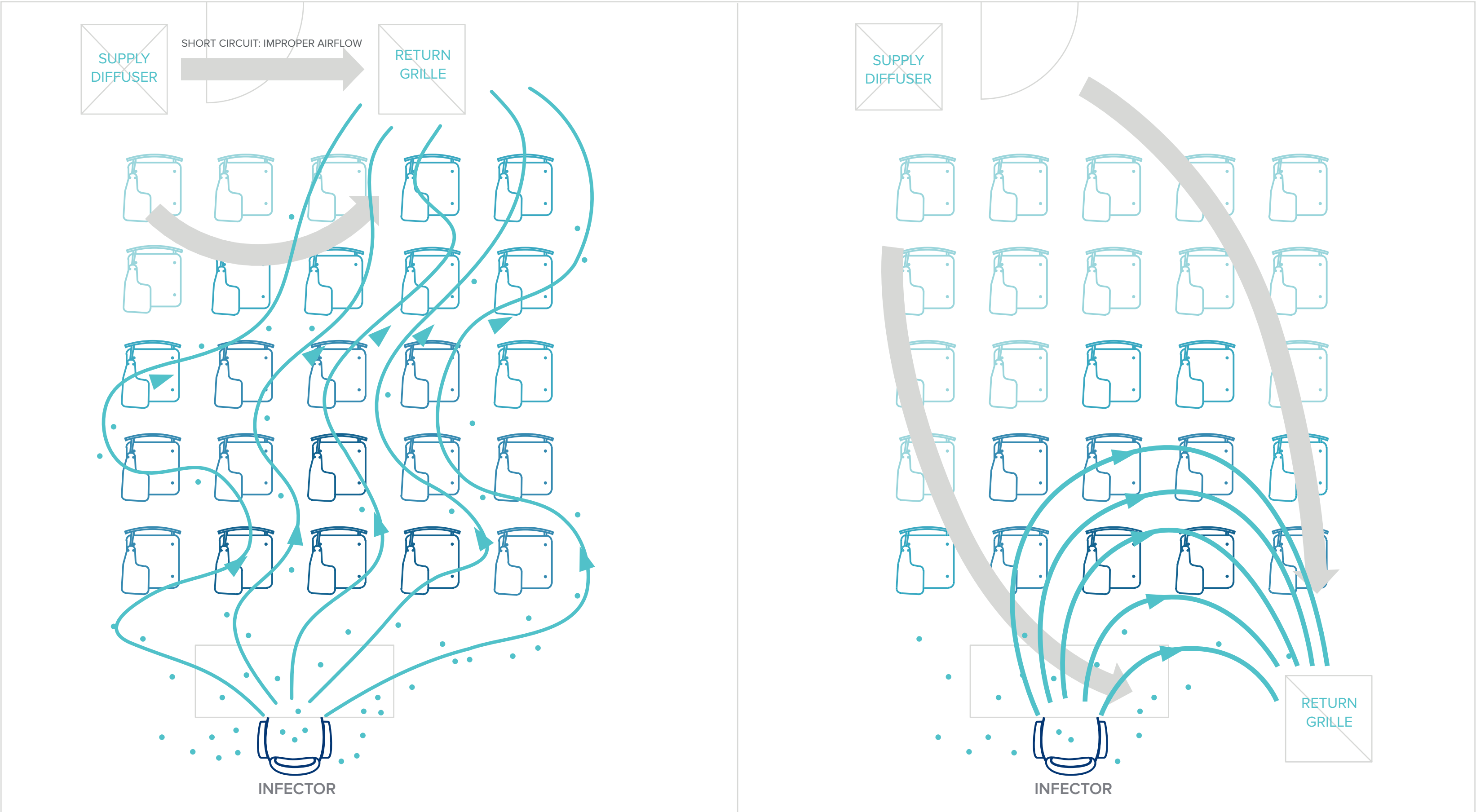
PROPER ROOM AIRFLOW

THE EXAMPLE BELOW SHOWS TWO DIFFERENT RETURN GRILLE PLACEMENTS IN A CLASSROOM WITH A SICK TEACHER. A TEACHER POSES THE HIGHEST RISK OF SPREADING INFECTIOUS DISEASES IN A CLASSROOM ENVIRONMENT AS THE MAIN SPEAKER.

The darker shades of blue indicate seats of students at a higher risk of infection.

Path of contaminants from the teacher to the exhaust grille.

General airflow pattern.



POOR
AIRFLOW

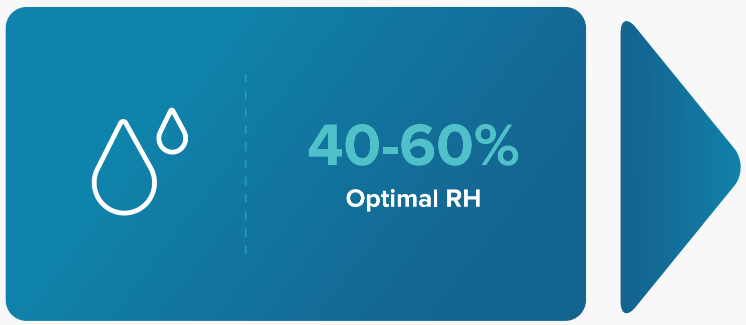
Supply diffuser and return grille are too close resulting in stagnant airflow and a build up of contaminants in the space. Many students are at a high risk of infections.

IMPROVED
AIRFLOW

Supply diffuser and return grille are on opposite sides of the room. Air sweeps across the room flushing away contaminates and only students in close proximity to the infected individual are at a high risk of infection.

02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)



RELATIVE HUMIDITY (RH)

The HVAC industry has long known that relative humidity can affect a virus' ability to transmit and propagate.

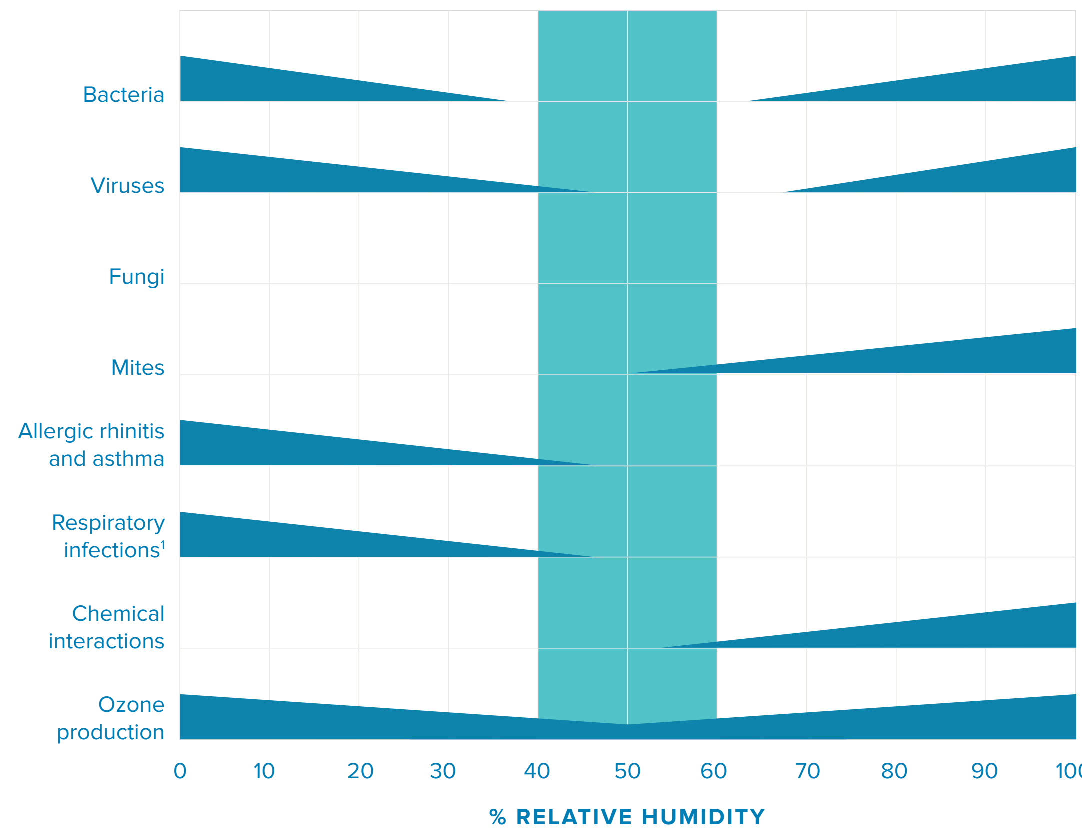
Optimal RH

As the Sterling Chart to the right demonstrates, viruses have a low ability to propagate between 40% and 60% RH. This is also true of bacteria, bronchial infections, and other irritants. Control of RH is an important factor to our health and well-being.

Although increasing humidification levels may be beneficial in reducing viral transmission, it can also create condensation within a building, which can lead to harmful long-term issues such as mold and building material damage. A thorough review of the building envelope should be undertaken prior to increasing RH levels. Controls and maintenance are important to ensure no unforeseen issues arise from the addition of humidification.

[4]Adapted from Sterling et. Al 1985–referenced ASHRAE Fundamentals, 2000 chapter 20, page 1

OPTIMUM HUMIDIFICATION RANGE FOR HUMAN HEALTH[4]



[1]Insufficient data above 50% RH.
E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, 1985 ASHRAE.

NOTES (Fillable):

02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

Consequences of Low RH

There are three main factors that, in general, make low RH a hospitable environment for viral spread.

Human Bronchial System

Resistance to viral infection is reduced with dried out bronchial passages, which will occur with persistent low RH. As RH is lowered in buildings, our noses, throat, and lungs become drier. These factors result in a perfect storm. It is no coincidence that viruses are their most deadly over the long winter months in the Northeast, as we all spend more time in the warm, dry, confines of our homes and buildings.

Viral Buoyancy

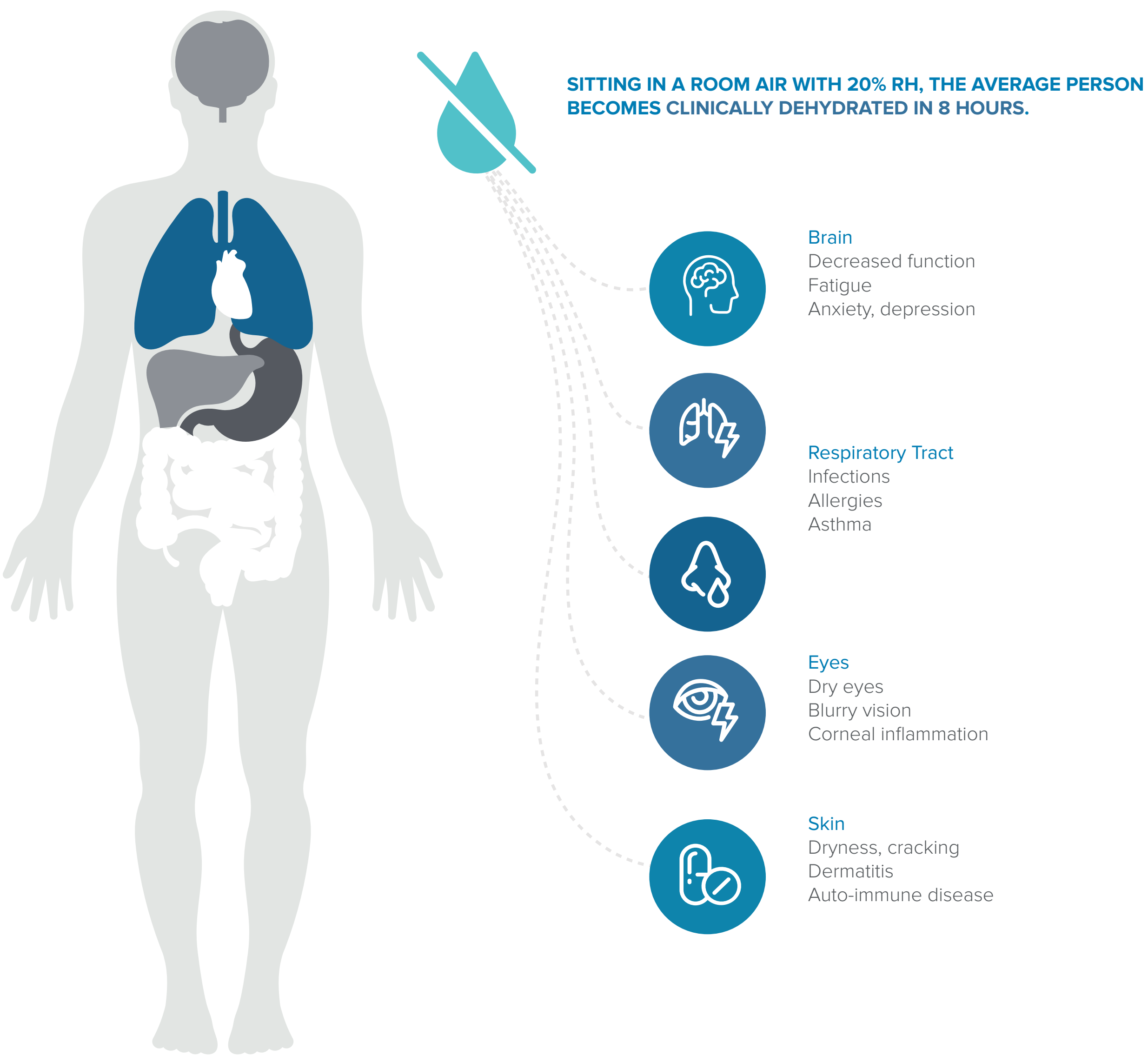
With lower humidity content, viral particles tend to stay buoyant in the air for a longer period of time since they are smaller in diameter, not as heavy, and devoid of moisture.

Viral Virulence

Virulence is a virus' ability to infect a host. Many viruses' "lifetime" is extended with either low or high RH. Although the existing research isn't conclusive, this particular phenomenon may not be true for the Sars-Cov-2 epidemic[5]

[5]See "Mechanistic Insights Into The Effect Of Humidity On Airborne Influenza Virus Survival, Transmission And Incidence" Marr, et al, 2019

OUR HUMAN HVAC SYSTEM



02
IAQ FUNDAMENTALS

INDOOR ENVIRONMENT FACTORS THAT IMPACT VIRAL TRANSMISSION (CONT.)

OCCUPANT DENSITY

Buildings in which occupants are in close proximity to each other are prime candidates for virus transmission. These include classrooms, auditoriums, dining halls, open office spaces with lots of cubicles, sports arenas, and even dormitory lounges. Spaces with higher occupant densities will have higher risk potential, simply because more people are subject to inhaling an infected person's exhaled aerosols.

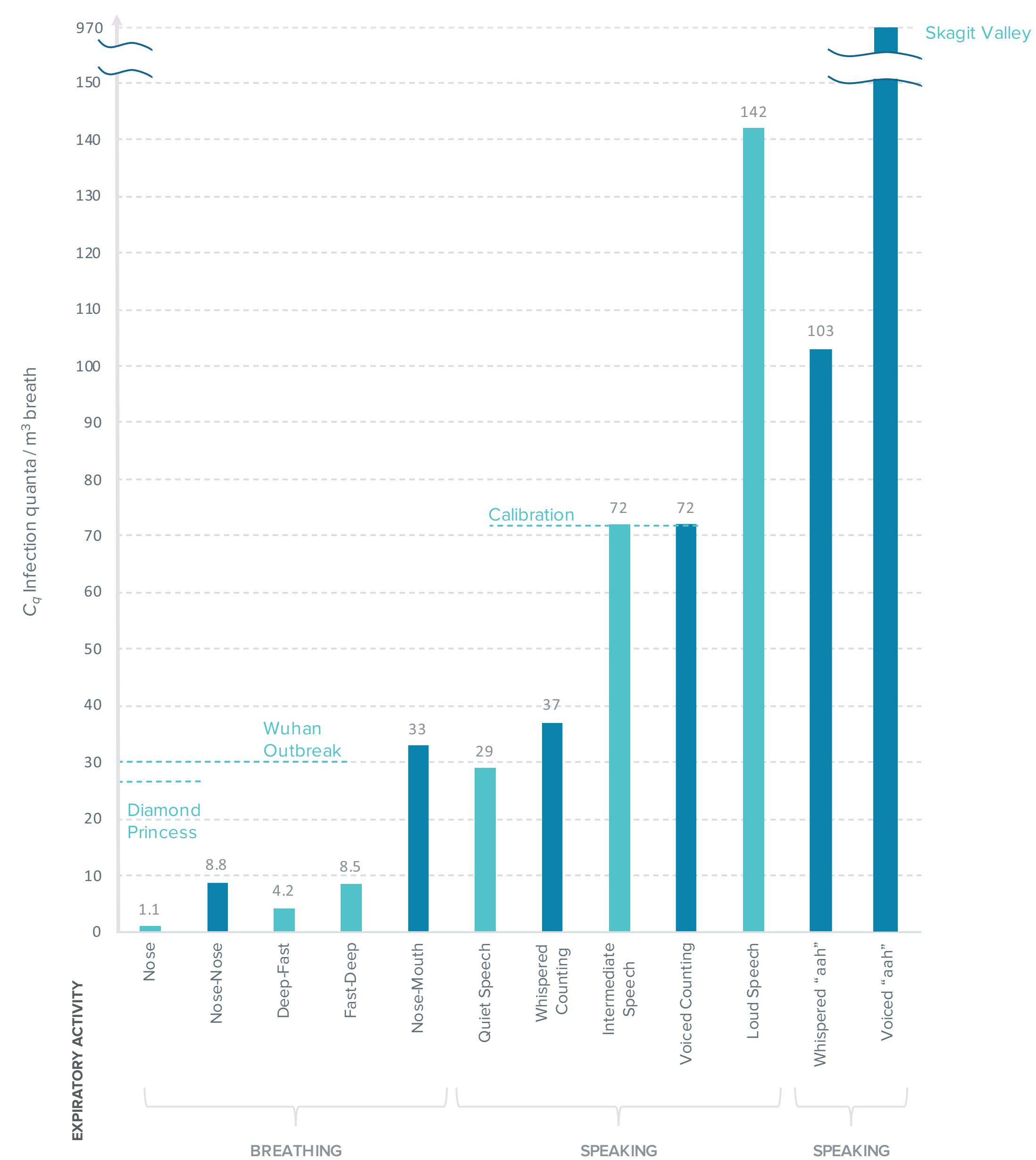
OCCUPANT BEHAVIOR

In addition to addressing occupant density, consideration of "what people are doing" in a space is another crucial factor in the spread of SARS-CoV-2. As the chart to the right indicates, occupant behavior has a huge impact on the amount of viral spread. Consideration of occupant behavior hazards in various building spaces can help identify high hazard areas.

As the Infection Quanta Chart depicts, the "what" we are doing is a very important consideration of potential transmission. A lecture classroom with one person speaking at 72 Quanta/m^3 and 20-30 people quietly listening at 4-5 Quanta/m^3 will be a much lower risk compared to an equivalent sized room with a choir of people singing, each emitting particles at 970 quanta/m^3.

The Wells-Riley model is an equation that can be used as a means for predicting infection risk based on variables such as probabilities of new infections, new infections, number of susceptible individuals, number of infectors, quanta generation rate, pulmonary ventilation rate, exposure time and uncontaminated air flow rate.[7]

INFECTION QUANTA CHART[6]



6Infection quanta is defined as a measurement of infectious quantity of expelled air per occupant. Infection quanta (denoted as Cq in the adjacent chart) is measured in terms of m^3 per breath (Definition and chart obtained from *MIT COVID-19 Safety Guideline v4.1-1)*

7Wells-Riley Model Equation: P=C/S=1-e^(-Iqpt/Q). Variable definitions and more information can be found in *ASHRAE's Building Readiness Guide*

IAQ FUNDAMENTALS TAKEAWAYS

1
VIRAL SPREAD

Viral spread is typically through inhalation of airborne contaminants in indoor air or fomite (surface) contact.

2
OUTDOOR AIR VENTILATION

Outdoor air ventilation is critical to dilute the pathogen concentration in indoor spaces.

3
PROPER FILTRATION

Proper filtration is key in limiting the viral spread with recirculated air systems, since this offers a mechanism to capture contaminants.

4
GOOD AIRFLOW

Although the amount of outside air ventilation is very important, how it moves through each space is also important.

5
40%-60% RELATIVE HUMIDITY

Relative humidity between 40% to 60% is the optimal range for decreasing the virulence and buoyancy of viruses and maximizing the bronchial system resistance.

6
OCCUPANT DENSITY & BEHAVIOR

Occupant density and occupant behavior are critical factors in viral transmission. The higher the density and vocal activities, a higher chance of viral transmission exists.

03

SECTION THREE

STAKEHOLDER ROLES

03
STAKEHOLDER ROLES

STAKEHOLDER RESPONSIBILITIES

Improved building IAQ is an important defense in protecting the health of building occupants. Although building HVAC improvements alone will not combat the spread of SARS-CoV-2 in the indoor environment, these improvements can play a key role in reducing the occupants' risk of infection from viral spread.

To ensure the safest indoor environment possible during an epidemic, all members of the academic community need to support this effort.

THE ROLE OF THE CAMPUS COMMUNITY

Students and staff have a critical role to play in stopping the spread of viruses, as they represent the largest population for any campus.

Staff and students can be part of the solution by doing the following[8]:

» Comply with State and campus social distancing, hygiene and mask policies

» Avoid lingering with others in dining halls, library reading rooms, classrooms or other spaces or participating in other types of social gatherings

» Do not adjust IAQ equipment. For example, local air purifier units should not be shut off by staff due to noise or drafts or other concerns[9]

» Leverage simple technologies to improve IAQ. Examples include opening windows when allowed, using room humidifiers with proper maintenance and hygiene as described elsewhere in this guide. Use of humidification devices should be cautioned and carefully considered as potential for condensation and mold issues may arise.

THE HUMAN ELEMENT

[8]See *"Schools for Health-Risk Reduction Strategies for Opening Schools", June 2020, Harvard T.H. Chan School of Public Health*

[9]Facility staff to determine optimal location to avoid drafts and excess noise

03
STAKEHOLDER ROLES

STAKEHOLDER RESPONSIBILITIES CONT.

MIT provided an open-source tool[10] that calculates the longest amount of time people can safely remain in an indoor environment as a function of occupancy, space use, activity, mask policy, mask usage and effectiveness and compliance[11], along with several other variables. This calculation tool assumes a single occupant in the space is infected with the COVID-19 virus. If either one of the calculated maximum values are exceeded (maximum occupancy or maximum exposure time), all occupants should be considered a 'contact' with regards to contact tracing. *Although guidance is ever changing, the CDC currently considers 'contacts' as any individual within 6' of an infected person for a total of 15 minutes.* The table to the right is a representative sample of typical space types for college campuses.

The model results are highly sensitive to mask usage compliance, especially with regards to how the mask is worn, i.e., whether it fully covers the nose and mouth. Although IAQ is important to mitigating the spread of viruses, review of the tool results indicate mask use is critical in providing a safe environment for the occupants in a space for a long duration.

[10]*Beyond Six Feet: A Guideline To Limit Indoor Airborne Transmission of COVID-19 (Bazant and Bush), Sept 1, 2020*

[11]The MIT tool gives the user several options to define mask effectiveness. Please review tool for further guidance.

TYPICAL INDOOR SAFETY GUIDELINES—RISK ASSESSMENT EXAMPLE

Room Type	Classroom	Lecture Hall	Auditorium	Athletic Facility	
Typical Square Footage (sq. ft.)	750	1,000	2,000	4,000	Notes:
Typical Ceiling Height (ft.)	10	15	20	25	
Ventilation Air Change (ACH)	3.0	7.5	5.0	2.0	
Breathing Flow Rate	0.7	0.7	0.7	1.5	*Based on activity: 0.5 = rest, 1-3 = active*
Maximum Occupancy (if all occupants wear cloth mask correctly)	33	98	176	64	
Typical Class Runtime (hour)—equivalent to maximum duration of safe activity with all occupants wearing mask	2	3	3	2	*Based on activity: 0.5 = rest, 1-3 = active*
Maximum Exposure Time (if no occupants are wearing a mask)	0.055	0.053	0.06	0.063	*# of hours occupants can safely be in space if no masks are worn*

03
STAKEHOLDER ROLES

STAKEHOLDER RESPONSIBILITIES CONT.

THE ROLE OF ADMINISTRATION STAFF

No cause will be successful without a clear prioritization of the IAQ Action Plan, buy in from all stakeholders and championing of the initiative. While facility management is the natural implementer of this initiative, to be truly successful campus administration must support this initiative at many levels.

Although most of this document focuses on technical aspects, the cost of improving IAQ across a campus must be understood and planned for. Administrators are ultimately responsible for aligning budgets with the IAQ Action Plan. Budgets will have to be adjusted to provide for both ongoing routine activities, such as provision of fan belts, filters, etc., but also plan out capital upgrades, such as air cleaning technology and fixing air handling units. Proper development of the IAQ Action Plan described in this document will provide administrators with the information they need to understand relevant issues and set priorities. This IAQ Action Plan puts forth procedures, guidelines and steps that should be taken with regards to modifying and optimizing the existing HVAC system in order to ensure the best mitigation strategies are being enacted throughout the facility. This IAQ Action Plan provides a list of procedures and processes for implementation that should be followed for the most effective indoor air quality benefits.

THE ROLE OF ADMINISTRATION STAFF

IAQ ACTION PLAN LEADER

Provide support for engineering staff

Communicate importance of Action Plan to all Campus stakeholders

Work with 3rd party stakeholders (such as NYSERDA, ASHRAE, CDC and DOH) to embrace best practices

ROUTINE MANAGEMENT

Allocate resources for ongoing IAQ (fan belts, filters, etc)

Communicate best practices for IAQ, and other infection control initiatives (social distancing, masking, etc)

Support initiatives for continuous monitoring of IAQ

CAPITAL PROJECT MANAGEMENT

Allocate resources for evaluation of capital upgrades

Evaluate recommendations for capital improvements

Align capital improvement request with campus budget.

03
STAKEHOLDER ROLES

STAKEHOLDER RESPONSIBILITIES CONT.

THE ROLE OF MAINTENANCE STAFF

Maintenance personnel are the front-line observers of IAQ and the eyes and ears of the building's operations team. Due to deferred maintenance, age, or other factors, some HVAC systems do not operate as originally designed. Existing HVAC systems often suffer from inadequate filtration, low air exchange rates, little to no outdoor air, in addition to a host of other issues.

As the employees most responsible for the day to day operation and maintenance of the HVAC equipment, maintenance staff need to ensure best IAQ practices on a continuous basis. Ensuring that ventilation levels are correct (both total and outdoor air), belts are maintained, dampers are working correctly, and the BMS is working correctly, are just some of the tasks that operations and management need to perform to ensure proper IAQ. See the *HVAC Systems Evaluation Checklist* and *Epidemic HVAC Mitigation Strategies* sections for greater detail.

The reasons for deferred maintenance and poor conditions may be well beyond the control of the maintenance staff. However, maintenance staff can minimize the duration of IAQ issues by being proactive and identifying/correcting maintenance issues early on and informing management of issues which need support. The maintenance staff shall play an active role in said IAQ Action Plan. Maintenance staff should participate in the broader HVAC Mitigation Strategy discussions as per *Section 5,* as well as perform systems evaluations as listed in *Section 6*.

MECHANICAL SPACE COMPARISON

Dirty Mechanical Space

Clean Mechanical Space

03
STAKEHOLDER ROLES

STAKEHOLDER RESPONSIBILITIES CONT.

THE ROLE OF ENGINEERING/FACILITIES MANAGEMENT STAFF

The engineering and facility management staff, along with the hired professionals (Cx, TAB, engineers, etc.), will most likely lead the day to day effort to improve IAQ on the campus. They will oversee the development of the IAQ Action Plan and provide administrators the information needed to prioritize competing priorities and budget for improvements. Engineering and facility management staff will be expected to understand the campus IAQ issues and recommended mitigation steps and be able to successfully implement them. Engineering and facility management staff must ensure maintenance staff receives necessary training in issues related to IAQ, as well as safety practices unique to working in *ECiP (Epidemic Conditions in Place).*

Engineering and facility management staff need to understand the installation cost and higher operating cost associated with providing better IAQ, which may result from the items noted in the Understand what Drives Up Costs graphic on the right.

ASHRAE's Building Readiness Guide sets forth potential energy savings considerations that can be taken in order to offset the potential increase in energy resulting from the IAQ strategies. Some considerations for energy efficiency strategies are noted in the Considerations for Energy Savings graphic on the right.

Understand what DRIVES UP COSTS
Increased heating and cooling loads due to higher ventilation rates
Increased run hours of major equipment due to implementation of purge cycles
Increased electricity usage and demand due to higher pressure drop air filters and higher airflow rates
Increased plug loads due to greater use of portable HEPA filters, humidifiers, etc.

Considerations for ENERGY SAVINGS
Utilizing reduced occupancy and/or closures, the facility can operate HVAC systems under their unoccupied modes (i.e. setback temperatures or relaxed setpoints)
ASHRAE Guideline 36-2018 – High-Performance Sequences of Operation for HVAC Systems
With an understanding of the 'what', 'why' and the 'how much' of the IAQ improvement effort, engineering and facility management staff will be better able to communicate the most important needs to the administration management.

NOTES (Fillable):

03
STAKEHOLDER ROLES

STAKEHOLDER ROLES TAKEAWAYS

1
ALL STAKEHOLDERS MATTER

All campus stakeholders have a role in realizing improved IAQ

2
OPEN COMMUNICATION

Open Communication is key. It is important that issues in the mechanical room find a clear path to the top of the organization and the big idea behind the importance of IAQ is understood by all stakeholders

3
PROJECT LEADERSHIP

In general, the likelihood of success will be greater with a project leader.

4
UNDERSTANDING ROLES

The more stakeholders understand their roles and fully embrace the importance of this endeavor, the more the level of improved IAQ will be realized.

04

SECTION FOUR

IAQ ACTION PLAN

04
IAQ ACTION PLAN

IAQ ACTION PLAN PROCESS

The IAQ Action Plan serves to provide a comprehensive process for improving IAQ and occupant safety in campus buildings during the COVID-19 pandemic. The intent is to highlight the high-impact improvements that higher education staff can implement in-house. However, to set forth an inclusive guide that enables colleges and universities to customize an approach to meet their needs and/or desired level of intricacy, lower-impact improvements and areas where professional services may or should be relied upon are also included.

This plan is primarily based on the building HVAC system recommendations from *ASHRAE's Epidemic Conditions in Place (ECiP) building readiness* and *reopening guidance* documents. Content is provided from additional resources where deemed appropriate to present a comprehensive guide. The plan assumes buildings are in operation, with varying levels of occupancy.

Although the IAQ Action Plan is presented as a linear process, beginning with the evaluation of existing HVAC systems and concluding with ongoing commissioning guidance, it is also designed to allow users to jump into any step of the Plan and have a clear understanding of the steps required to achieve any given action item.

IAQ ACTION PLAN PROCESS

04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION

Gathering a thorough understanding of the status of the buildings on campus is a critical first step in determining how to combat inadequate IAQ. In five steps, the campus evaluation will provide insight into determining the current state of existing system operations and identifying potential areas for improvement on campus.

STEP 1 | Form a COVID Response Committee

The COVID Response Committee will take the lead on executing this IAQ Action Plan. Consider including the following stakeholders for the committee:

» Engineering/Facilities management

» Operations and Maintenance personnel

» Administration staff

» Environmental Health and Safety staff

» Campus Community Member: Students and/or faculty with applicable expertise, who have the perspective of working and studying within the facilities

STEP 2 | Identify High Risk Buildings and Spaces

Time and resources in order to complete this task will vary depending on size of the campus, available staff and complexity of HVAC systems. To focus on high impact improvements and to economize time and resources, high risk buildings and spaces should be identified and given priority for system evaluation and improvements. Although defining a space as high risk is quite subjective, in general, a building or space could be considered high risk for any of the following reasons:

» High occupant density—a space above the recommended occupant density as defined by *ASHRAE 62.1-2016 Table 6.2.2.1*[12]

» Extended occupancy time (e.g., over one hour in same room)[13]

» Activities occur that prevent PPE and/or distancing protocols (e.g., Dining)

» High probability of occupancy by infectious or at-risk individuals

» Areas with known HVAC deficiencies (e.g., lack of ventilation, poor IAQ, poor air distribution, etc.)

» Areas without either operable windows, mechanical ventilation, or other scenarios that would enable infectious spread (e.g., toilet flushing)

» Areas that have been converted in use (e.g., storage space to offices) that may suffer from subpar ventilation and HVAC systems

Common high risk buildings within a higher education setting include (in alphabetical order):

» Athletic Facilities; with focus on high density areas such as locker rooms

» Dining Halls

» Dormitory Buildings

» Lecture Halls

» Music and Theatre Spaces—due to natural activity of singing and loud speaking

» Other facilities where large assemblies occur

» Student Health Facilities

» Toilet Rooms

[12] NYS Code adopts ASHRAE 62.1-2016
[13] ASHRAE states extended occupancy is any occupancy over one hour in the same room. The CDC defines extended occupancy as over 15 minutes under close contact (less than 6' separation)

04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION CONT.

It is recommended that all members of the COVID Response Committee participate in a COVID risk assessment of the buildings and spaces on campus to identify existing space use profiles and evaluate the risk level for occupants. This activity consists of:

Review Existing Space Use Profiles:

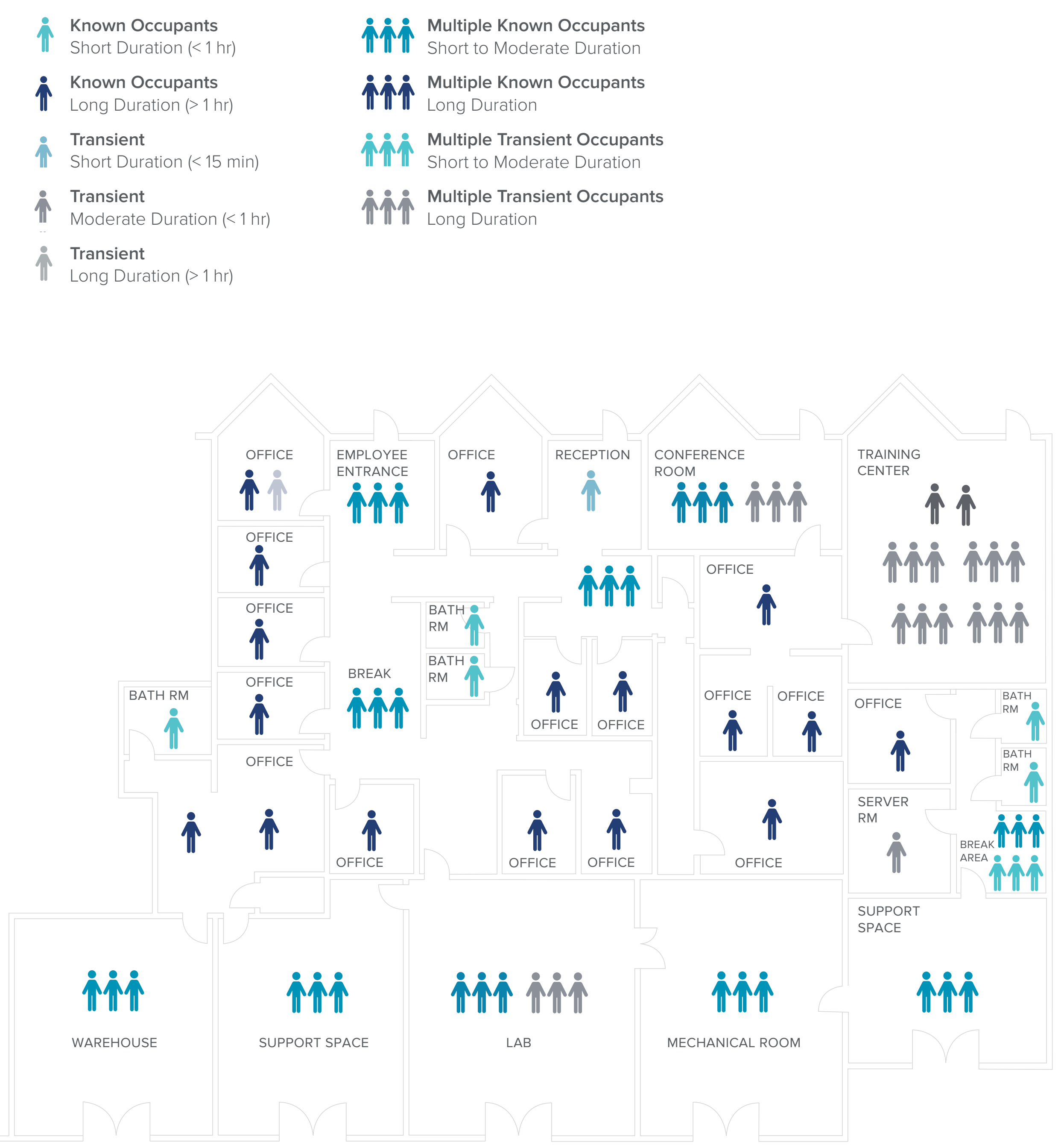
- Identify how each space is used and whether it was designed and intended to be used in that manner. This is especially important for high risk areas (*see previous section*), and also areas which have been converted from previous use (e.g., storage area converted to office, etc.).
- Identify occupancy levels in each space, the duration of time spent in each space, and occupant density. Compare occupant density to recommended levels-as set by *ASHRAE 62.1-2016 Table 6.2.2.1*.
- Identify potential risk level of the type of occupants likely to occupy the space. As an example, older and special needs populations are higher risk.
- Record any known high risk qualities of a space or building (using the list of high risk indicators (*see previous section*)

Please see representative image of hazard assessment (3Flow, Inc. Presentation—Aerosol Pathogen Response Plan: New Methods to Help Mitigate Risk Indoors).

HVAC System Configuration:

- Identify low risk vs. high risk system configurations. Low risk includes ventilation systems with code-compliant outdoor air ventilation rates, good air distribution, MERV 13 filters or higher, or air cleaning devices. Higher Risk includes systems with non-code compliant outdoor air ventilation rates, poor air distribution, filters rated below MERV 13 or no air cleaning devices.

3FLOW PATHOGEN RESPONSE PLAN[14]



[14]This representative image of a hazard assessment is adopted from the 3Flow, Inc. Presentation—Aerosol Pathogen Response Plan: New Methods to Help Mitigate Risk Indoors).

04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION CONT.

Determine COVID Risk for Occupants:

» After analyzing each space and building in detail and identifying the potential high risk attributes for COVID spread, assign a COVID risk level indicator to each space and/or building, such as the example to the right.

Additionally, there are tools available to assess the risk level of spaces, such as:

» *Laboratory Ventilation Risk Assessment (LVRA) tool*. This tool evaluates lab spaces to establish minimum, safe ventilation rates.

» *MIT COVID-19 Indoor Safety Guide tool*. This tool estimates the exposure time for contracting COVID-19 based on number of people in a space and the time duration of exposure.

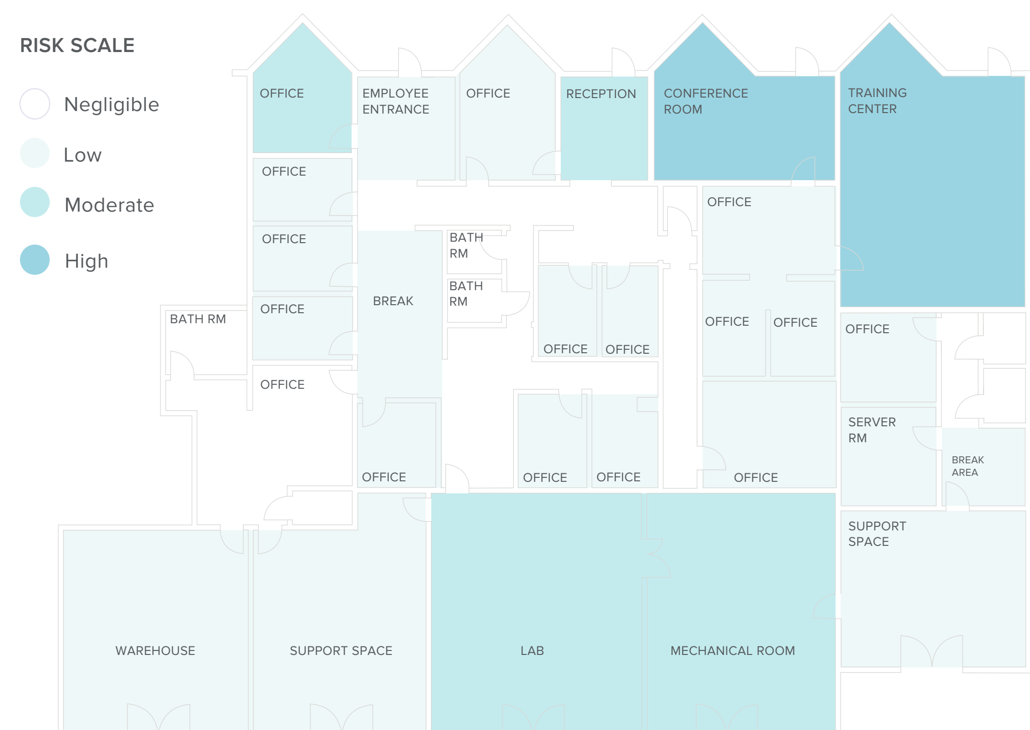
» *Setty COVID-19 Airborne Transmission Infection Rate Estimator*. This tool predicts the probability of infection in a space based on several factors, including occupancy levels, exposure times, outdoor air rates, filtration levels, disinfection, and air change rates.

» *University of Colorado—Aerosol Transmission Estimator*. This tool estimates the propagation of COVID-19 by aerosols in order to evaluate the potential risk associated with a particular space.

Be sure to understand the basis of these types of tools and the potential limitations of the accuracy of the results. County/Federal health departments have ever changing guidance that should be checked in order to understand the full range of limitations and potential overrides to the tools listed above. With certain unknown factors, such as the number of infectious particles emitted by an infectious person, the accuracy of the results should be considered as in the context of campus wide safety factors.

SPACE RISK ASSESSMENT

Risk Band	Description	Attributes
1	Low	≤ 1 Known Occupant Limited to No Visitors Proper HVAC Operation
2	Moderate	Known Occupants Limited Visitors w/ Short Duration Adequate Spacing of Occupants Proper HVAC Operation
3	High	Known Occupants Visitors w/ Extended Duration Mixed Social Space and Close Contact Ventilation Issues Aerosol Generating Procedures or High Risk Activity (Singing, Physical Activity, Toilet Flushing, Medical Procedures, etc.)



04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION CONT.

With the COVID risk level determined for each space and building, prioritize the highest risk spaces and buildings to continue on with the next step of this IAQ Action Plan: HVAC Systems Evaluation.

Step 3 | HVAC Systems Evaluation

The HVAC Systems Evaluation will provide an understanding of the existing conditions, and system modification requirements and capabilities to improve IAQ. The staff time and resources, as well as the money required for outside consultants will vary depending on size of campus, staff availability and complexity of HVAC system.

Start with evaluating the systems that serve the high risk spaces within the buildings identified as high risk in *Step 2 – Identify High Risk Buildings and Spaces*.

Next, gather and review building and system documentation[15] relevant to the high risk buildings and spaces. ASHRAE identifies the following key documentation that should be gathered at the project commencement. Note that it is more efficient to gather all documents at the start of a project, so it is readily available when needed in future steps. Documents which are recommended include:[16]

- Most recent design documents, specifically the HVAC and Plumbing Water systems construction documents
- Record documents (as built, marked up drawings, and specifications received from the Contractor at the conclusion of construction)
- Original, approved equipment and system submittal documents
- Systems manuals and project closeout documents
- *If a systems manual for normal operations is not already in place, refer to ASHRAE Guideline 1.4-2019 Preparing Systems Manuals for Facilities for guidance on creating one*
- Controls and Building Automation System (BAS) drawings and sequences of operation and initial system parameters
- Equipment control wiring diagrams and troubleshooting guidelines
- Service contracts and maintenance logs
- BAS trend reports and alerts and notifications reports
- Most recent Testing, Adjusting and Balancing (TAB) reports
- Most recent Commissioning Reports

[15] *ASHRAE Building Readiness page 6*
[16] The availability of good documents is always a challenge. While every effort should be made to get all available documents, more than likely existing documentation will have shortfalls, which can be addressed through field inspections.

Use the HVAC system evaluation checklist in Section 6 to evaluate each HVAC system and piece of equipment for:

- Existing operational issues, known deficiencies, etc
- Proper operation per design conditions and discussions with facility staff on current operation and any deferred maintenance and/or any temporary fixes to HVAC system including any known pitfalls.
- Deficiencies that should be repaired (examples include loose fan belts, disconnected actuators, frozen dampers, impediments to airflow and/or damper operation, incorrect outdoor air settings, etc.)
- Current filter level, installation quality, additional air cleaning device and capability of modification to align with ASHRAE's epidemic HVAC mitigation strategies. To effectively perform this objective, review the *ASHRAE recommended mitigation strategies* before conducting the system evaluation, with a focus on both pandemic (ECiP) and post pandemic mode (P-ECiP).
- Opportunities to reduce energy consumption, in concert with IAQ improvements.

Determine the need for a TAB Assessment and enlist the services of a TAB contractor, if necessary

If major deficiencies are identified which affect the airflow of any air handling units (AHUs) and/or exhaust fans during the HVAC system evaluation step, a TAB assessment should be conducted by a certified TAB professional. Organizations listed below are the main certifying agencies.

- *Associated Air Balance Council (AABC)*
- *National Environmental Balancing Bureau (NEBB)*

04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION CONT.

- *Testing Adjusting and Balancing Bureau (TABB)*
- *National Balancing Council (NBC)*
- *Other certifying body*

A TAB assessment includes the testing, adjusting, and balancing of HVAC systems by a certified contractor to achieve optimal system operation. The TAB contractor will make system adjustments to meet the desired performance which is established by the design engineer. Key variables include total and outdoor air volume for AHU (at minimum and maximum VAV position-if applicable), air volume for space (at diffuser level), exhaust airflows, and pressure relationships.

Testing establishes current equipment performance through the use of diagnostic and measurement instruments. Adjustment of systems involves modifying control and mechanical settings to achieve optimal equipment performance.

With respect to indoor air quality, ASHRAE recommends consideration of the following:

- To ensure that increased ventilation modifications do not create system functionality issues (ASHRAE Building Readiness 10-20-2020 p15)
- To ensure that increased ventilation modifications do not create new building and space pressurization issues (ASHRAE Building Readiness 10-20-2020 p18)
- To aid with evaluation of the maximum MERV rating that systems can accommodate in complex HVAC systems or systems serving critical buildings or spaces within buildings and to document static pressure of newly installed filters. (ASHRAE Building Readiness 10-20-2020 p22- 23)
- To ensure Energy Recovery Ventilation (ERV) systems are well designed and well maintained (*ASHRAE Building Readiness 10-20-2020 p47-64* and *ASHRAE Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems*)
- The TAB contractor's report should outline deficiencies with the units such as issues with filters, dampers, airflow, etc., and the necessary and determined corrective action items. The TAB report should be reviewed by campus engineering staff, with high priority IAQ issues considered for implementation.

STEP 4 | Document Findings

The results of the HVAC System evaluation should be included in a single HVAC System Evaluation Report, which notes all HVAC operational findings, deficiencies, and potential for epidemic mitigation strategies for each building system. The time and resources needed to complete this task will vary depending on size of campus, available staff members, and complexity of IAQ issue.

Below is a sample existing deficiencies table with example input data.

IAQ ACTION PLAN PROCESS

Deficiency Number	Existing Description	Notes	Photo
1	AHU-4, Belt disconnected		
2	AHU-6, birdscreen dirty	Note that this seems to be a recurring problem	
3	AHU-6, OA actuator is disconnected.		
4	AHU-6, Static pressure is disconnected	Sensor is located in MER-6	
5	Music Room-No Outdoor Air	Music room was converted storage space.	
6	AHU-8, Schedule is overriden currently 24/7)	Override is documented through trending.	
7	Nurses Office-Low RH		
8	AHU-10: SP sensor disconnected		
9	Global: Outdoor RH sensor is inaccurate		
10	Global: Toilet Exhaust seems low	Exhaust shaft appears to be dirty.	

04
IAQ ACTION PLAN

PHASE 1 | CAMPUS EVALUATION CONT.

STEP 5 | Rate Existing Systems

Using the results of the HVAC Systems Evaluation, the following chart can be used as a "self-reflection tool" to review progress in attaining IAQ improvements. The Minimum category requirements reflects good/ standard building practices. The Advanced category represents better IAQ strategies, while the Optimal category identifies the best IAQ solutions per ASHRAE for ECiP building operation.

NOTES (Fillable):

HVAC SYSTEM EVALUATION RATING

	Minimum	Advanced	Optimal
Ventilation Occupied Mode	Meet minimum outside air ventilation levels per local code and/or ASHRAE 62.1	Increase outside air ventilation to meet the desired exposure reduction without exceeding the space comfort conditions. Desired exposure reduction shall be defined by facility. The *Harvard/UC Boulder tool* suggests a target eACH of 5 or above.	Combine the use of increased outside air ventilation, filtration, and air cleaning devices to meet the desired exposure reduction in the most energy efficient way possible without exceeding the space comfort conditions
Ventilation Unoccupied Mode	Operate systems for 2 hours in occupied mode setting for both pre- and post-building occupancy	Operate systems in occupied mode setting either pre- or post- building occupancy for a duration of time that will achieve 3 changes of air volume using outdoor air to reduce the concentration of airborne infectious particles by 95%. Conduct 'Flush Time' Calculation using the *ASHRAE Building Readiness Equivalent Outdoor Air Calculator* to determine the amount of flush time needed to achieve the desired ACH.	*Operate systems in occupied mode setting either pre- or post- building occupancy for a duration of time that will achieve 3 changes of air volume* using outdoor air or equivalent outdoor air (incorporating the effect of filtration and air cleaners) to reduce the concentration of airborne infectious particles by 95%. Conduct 'Flush Time' Calculation using the *ASHRAE Building Readiness Equivalent Outdoor Air Calculator* to determine the amount of flush time needed to achieve the desired ACH.
Filtration	Typical standard building design of MERV 11	MERV 13 or 14, as systems can accommodate	MERV 15 or 16 or HEPA filtration[17], as systems can accommodate
Building Automation or Management System (BAS/BMS)	Existing system is in working order, alarms are cleared, and trends are downloaded for evaluation	Remote access capability Algorithms are set up to monitor and trigger events for low airflow (total and outdoor air), filter irregularities (missing filters, high pressure drop, etc), poor relative humidity, etc.	Additional control points such as CO_2 sensors, particle counter, relative humidity sensors, occupant counters, body temperature sensors, or other advanced technologies are installed Dedicated sequence of operations for "Infection Control" are established to enable the ECiP sequence at the push of a button
UVGI Air Cleaning Systems		Maintain UVGI system for air disinfection for high risk spaces	UVGI system for air disinfection purposes for all spaces (high and low risk)This may include provision of local air purification technologies (such as local HEPA filters with UVGI) for spaces without operable windows and no ventilation, and utilization of UVGI lighting-for high risk areas
Relative Humidity	Owner defined humidity conditions	Maintain design level relative humidity	Maintain relative humidity between the ideal range of 40% - 60%, particularly in high risk areas

[17]MERV 15 / MERV 16 / HEPA Filters are beyond what ASHRAE recommends. Note that the implementation of these filter types (if possible) would present a significant first cost as well as increase the AHU fan energy usage. If existing AHUs cannot accommodate such a filter, in-room/mobile HEPA devices should be implemented.

PHASE 2 | DEVELOP IMPROVEMENTS

Convene the COVID Response Committee to review and discuss the potential improvement items indicated in the HVAC System Evaluation Report (with TAB Report as part of documentation) to identify the items that should be pursued further. A Project Manager should be designated to keep meeting minutes for attendees and manage deliverables.

STEP 1 | Develop Scopes of Work

Prepare improvement descriptions that detail the scope of work necessary for the recommendations to be implemented by either in-house personnel or qualified service providers. Ensure all potential improvements comply with *ASHRAE Standard 62.1* and applicable codes. Include operational considerations when buildings are occupied during the epidemic.

STEP 2 | Obtain Cost Estimates

A cost estimate should be obtained for all potential improvements. Identify both first costs and continuous costs (such as filter replacements) to determine required allocations in the near term, and also for future budget allocations.

Where applicable, cost estimates should be itemized to distinguish between material and labor costs.

STEP 3 | Evaluate Impacts

For each potential improvement, identify the associated impacts of installing the measure. These impacts, when evaluated together, can help identify and prioritize the improvements that are most beneficial to proceed with. The impact level for the various variables (see discussion to the right) should be summarized in a table. Note that most of the impact review should be relatively brief and concise. Additional appendices, for energy and maintenance analyses for example, can be added for the impact areas that require more detail.

IAQ Impact: Identify the level of indoor air quality improvement the measure will provide. This can be done either in-house or by enlisting the services of an engineer or skilled contractor, depending on the level of analysis desired. There are several open-source risk-reduction tools available for use, such as:

- *Harvard/ UC Boulder Portable Air Cleaner Calculator for Schools.* This tool quantifies the effectiveness of portable air cleaning devices in conjunction with the amount of outdoor air ventilation in a space.
- *enVerid COVID-19 Energy Estimator.* This tool estimates the costs (first, operating, maintenance, carbon) associated with ventilation, filtration, and air cleaning strategies to combat COVID-19 aerosol transmission. It also calculates the effective Air Changes per Hour (ACH) for each improvement strategy and compares the ACH of various ventilation and filtration scenarios. The *Harvard Schools for Health report* identifies a minimum of 5 ACH as a target level to achieve, considering all ventilation, filtration, and air cleaning strategies.
- *ASHRAE Building Readiness – Equivalent Outdoor Air Calculator*. This tool calculates the effective, equivalent ACH (eACH) and associated flush time needed for a defined space. This tool sums up the effective ACH of the outdoor air, the filter and the potential UVGI or air purification device to obtain an equivalent ACH and determines the amount of time needed to flush the space using that equivalent ACH. Note that this tool and its associated calculations are done so from a viral perspective and should not be used to reduce outdoor air flow rates for any other reasons. This tool does not address other contaminants of concern such as VOCs.

System Functionality & Compatibility Impact: Identify the level of system modifications necessary to enable and sustain each potential improvement.

Maintenance Impact: Identify the level of additional maintenance time and cost associated with each potential improvement.

Occupant Comfort Impact: Identify the level of impact to comfort (ex. ability to maintain temperature and humidification levels) for each potential improvement, if applicable.

04
IAQ ACTION PLAN

PHASE 2 | DEVELOP IMPROVEMENTS CONT.

Resources Needed: Identify the level of assistance needed to evaluate and implement each improvement strategy (ex. in-house = low vs. external = high).

Implementation Cost: Identify the level of cost for each potential improvement.

Energy Impact: Identify the level of energy use and cost impact for each improvement strategy.

The following table to the right provides an example energy cost analysis comparing MERV-8 filters to MERV-13 filters.

STEP 4 | Prioritize Improvements

Prioritization can be made to some extent based on ease of implementation. Measures that are easy to implement should be implemented first. Budget concerns and deferred maintenance need to be taken into account when categorizing measures. Additionally, depending on the impacts identified from Step 3, determine the measures to further prioritize by considering the following:

- Classify improvements as a function of impact.
- Prioritize proper system functionality and maintenance routines by correcting any critical issues identified during the *HVAC System Evaluation*. Prioritize issues that would prevent the system(s) from functioning in accordance with the systems' original design. Examples would be issues which would affect total airflow (i.e., duct leakage issues, loose belts, control issues). Note that while resolving duct leakage issues may be difficult to achieve, they should be investigated and mitigated to the best possible extent.
- Prioritize increased outside air to spaces and treating return and/or supply air to spaces via mechanical filtration.
- Consider both the space risk and identified impacts when identifying priorities.

Document decisions made based on prioritization of recommendations.

FILTER COMPARISON

Filter Comparison				
A	Fan Efficiency	75%		
B	Load Factor	75%		
C	Sample Unit Airflow	2,000		
D	Labor Rate ($/hr)	$70.00		
E	Electrical Rate ($/kWh)	$0.10		
	Filter Type	**MERV-8**	**MERV-13**	**Calculations**
F	Replacement Cost	$20.00	$22.50	
G	Replacement Interval (# changes/year)	3	4	
H	Replacement Time (hours)	0.5	0.5	
I	Initial (Clean) Pressure Drop ("w.c.)	0.25	0.3	
J	Dirty Filter Pressure Drop ("w.c.)	0.5	1	
K	Annual Hours of Operation (hours)	3,920	3,920	*
L	Annual Maintenance Cost ($)	$30.00	$90.00	= F x G
M	Annual Labor Cost ($)	$105.00	$140.00	= D x G x H
N	BHP	0.16	0.27	= C x (I +J) / (2*6,356 x A)
O	Demand (kW)	0.09	0.15	= 0.746 x B x N
P	Annual Energy Usage (kWh)	345.07	598.11	= K x O
Q	Annual Energy Cost ($)	$34.51	$59.81	= E x P
R	Total Annual Cost ($)	169.51	$289.81	= L + M + Q
S	Cost Percent Increase (%)	-	71%	

*Space open 14 hours a day, 7 days a week, 40 weeks a year.

04
IAQ ACTION PLAN

PHASE 3 | IMPLEMENT SYSTEM MODIFICATIONS

STEP 1 – Obtain Approvals

Present the results of the recommended improvements analysis to the appropriate senior managers or administrators for implementation approval.

STEP 2 – Implement Improvements

» Implement Improvements in order of *designated priority as identified in Phase 2, Step 4*.

» Issue work orders for in-house maintenance personnel or purchase orders for qualified service providers that include the improvement descriptions per the *Document Findings step*.

» For BMS updates, make small changes to the system in incremental periods and monitor for a few days or through some varying weather conditions to make sure the system and building(s) is responding to the changes as expected. (*ASHRAE Building Readiness 03/16/2021 p15*). Have the Commissioning Agent or Control Contractor verify and document the effect of the changes through key trend reports and physical measurements or standalone data loggers.

STEP 3 – Update Systems Manual

The ASHRAE readiness guidance document recommends updating the Systems Manual to include new modes of operation for the facility, based on learnings from pandemic time period operation.[18]

Documenting the lessons learned will aid the facility in being prepared for future pandemics and also give the campus a tool to improve indoor air quality on a regular basis.

Items to include in the Systems manual include:

» Filter replacement schedule (with cut sheet and frequency)

» Minimum outdoor air settings and total airflow (per air handling unit)

» Recommended airflow-per space

» Relevant maintenance documents

» Documentation of "pandemic mode" sequence of operations, which should include:

  » Indicate the systems that will remain online without alterations

  » Indicate the systems that will remain online with alterations – detail special provisions, revised sequences of operations, BAS checks to ensure proper mode is engaged

  » Indicate which systems will be de-energized

  » Outline daily activities and documentation that might be different than the normal facilities check. Include updated data logs and forms as needed.

  » Anomalies which were documented when switching from normal operation to pandemic mode.

  » Documentation of Implementation of action items from this IAQ Action Plan.

NOTES (Fillable):

[18]System Readiness manual, page 61

04
IAQ ACTION PLAN

PHASE 4 | ONGOING COMMISSIONING

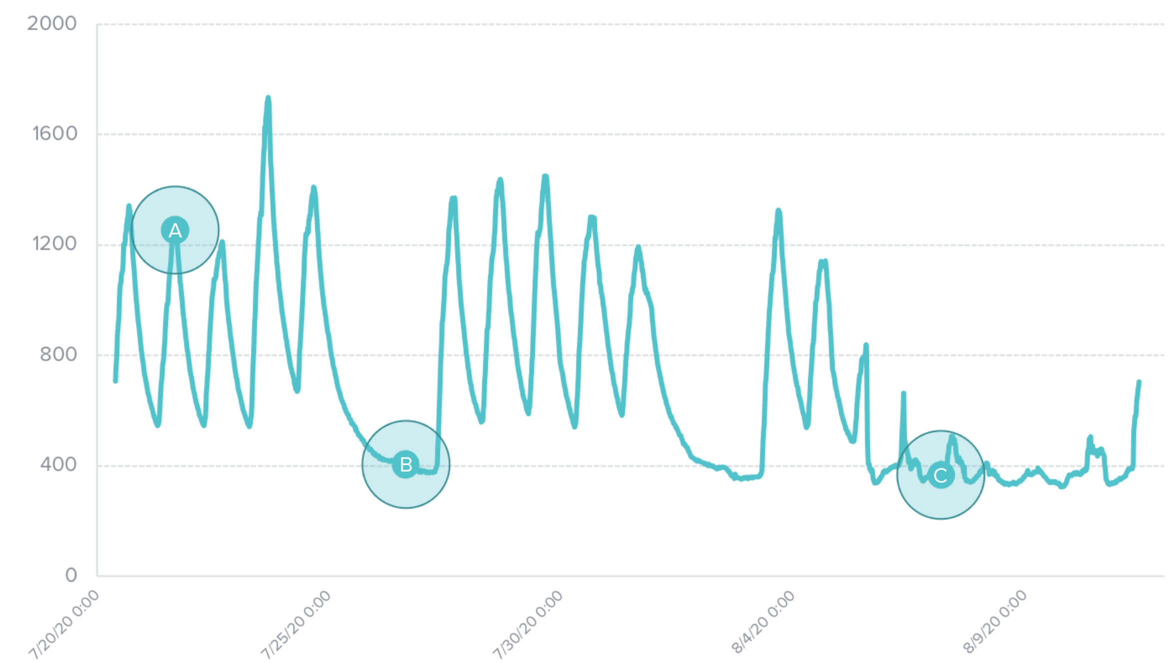
Ongoing Commissioning as defined by the Energy Systems Laboratory (ESL), a division of the Texas Engineering Experiment Station, is an ongoing process to resolve operating problems, improve comfort, and optimize energy use. Ongoing commissioning is recommended to ensure that, over time, systems will continue to operate as necessary to meet facility requirements. Ongoing commissioning will provide insight on the performance of HVAC systems and reveal system adjustments that are necessary. Examples of items for an ongoing commissioning plan include:

- » Verify airflows as compared to existing equipment schedule
- » Ensure outdoor air dampers function properly
- » Ensure ductwork and AHU cabinets are free from leakage and corrosion
- » Trend and review relative humidity readings. Review with staff if critical zones should be considered for local humidification.
- » Verify coils are clean and there is no standing water in drip pans
- » Ensure filters are installed correctly with no gaps around frame

The chart to the right is illustrative of the utilization of CO_2 loggers for the purpose of ongoing commissioning. The CO_2 readings show that there was a typical daily peak (approximately 1,400 to 1,600 ppm). Recognizing that the CO_2 concentration was typically increasing throughout the day and baselining at nighttime and weekends, a commissioning agent was able to deduce that the building fresh air was compromised. Similar to the Classroom Ventilation Metaphore in *Section 2*, without proper exchange air for the building, pathogens within air will build up, which is not a hygienic path forward.

After inspection with the HVAC service technician, it was realized that due to a control issue, the outdoor air damper was, in fact shut. After fixing the issue (see note C), the CO_2 concentration returned to normal, thus giving assurance that the building space was now provided with ventilation air.

CO_2 CONCENTRATION—BEFORE AND AFTER VENTILATION WAS CORRECTED



A Daily peaks-typically 4:30-5:30 PM

B Weekend

C When Ventilation was Fixed

05

SECTION 5

EPIDEMIC HVAC MITIGATION STRATEGIES

05
EPIDEMIC HVAC MITIGATION STRATEGIES

ASHRAE CORE RECOMMENDATIONS

Detailed ASHRAE recommended guidance for HVAC systems during ECiP are presented in this section. For the short term, the *ASHRAE Core Recommendations for Reducing Airborne Infectious Aerosol Exposure Guidance* (1/6/2021) presented to the right, should be pursued along with any low-cost/no-cost projects identified from following this Action Plan.

For the longer term, the capital improvement projects identified from following this Action Plan, which will enable future-proofing from additional pandemics and improve the indoor air quality for the occupant's general well-being and increased productivity, should be considered and worked into capital budget planning. These projects may include:

- Thermal envelope improvements to allow for increased humidification
- Installation/upgrading humidification systems
- Upgrading filter racks or HVAC systems to allow for higher MERV rated filters
- Upgrading the BMS to monitor additional data points or allow for programmed modes of operations, such as a pandemic mode
- Pursuing an IAQ/IEQ certification such as Fitwel[22]

ASHRAE CORE RECOMMENDATIONS

Ventilation/Filtration/Air Cleaning

- Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards
- Use combinations of filters and air cleaners[19] that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems
- Only use air cleaners for which evidence of effectiveness and safety is clear
- Select control options, including standalone filters and air cleaners, that provide desired exposure reduction[20] while minimizing associated energy penalties

Air Distribution

- Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person. For situations where airflow issues occur, more than likely a professional engineer will be required to evaluate system and offer solutions.

HVAC System Operation

- Maintain temperature and humidity design set points[21].
- Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system
- When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply
- Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outside air intakes, and other sources to acceptable levels

System Commissioning

- Verify that HVAC systems are function as designed

[19] Third Party Testing Results and UL Certifications can help determine which air purification devices are effective and which meet the needs of each individual campus
[20] Desired Exposure Reduction: the desired reduction in the risk associated with occupying a space after the impacts of filters and other air cleaning devices areimplemented (i.e. risk for individuals being in contact with infectious aerosols is reduced)
[21] Although the ASHRAE Core Recommendations do not explicitly state a relative humidity range, the ideal range for occupant health is 40% - 60%
[22] Fitwel Certification: A building certification that supports healthier workplace environments to improve occupant health and produc-tivity. This certification indicates that an organization or building prioritizes wellness and health of its occupants. Any organization can apply for Fitwel Certification under the various pathways they provide: *https://www.fitwel.org/certification/*

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EPIDEMIC HVAC MITIGATION STRATEGIES

DESIRED EXPOSURE REDUCTION

When considering mitigation recommendations, ASHRAE recommends that:

» The recommendations be applied with specific consideration of each unique building and HVAC system

» All retrofits and modifications must not contradict ASHRAE guidelines and must continue to meet or exceed applicable codes and standards

DESIRED EXPOSURE REDUCTION

Outside air, filtration, and air cleaning strategies can be deployed in combination to achieve the desired exposure reduction goals of the campus while also factoring in comfort, energy use and costs. This can be achieved by evaluating the equivalent outdoor air of each strategy and selecting the package of strategies that meets the desired target clean air supply rate (expressed in air changes per hour (ACH). The equivalent ACH (eACH) impacts of each strategy are additive, meaning that by simply adding each strategy's eACH together will identify the total cumulative eACH for the space (ex. 2 eACH for filtration + 3 eACH for outside air = 5 eACH).

ASHRAE recommends prioritizing that systems meet outside air levels per code as a first step. ASHRAE then recommends that spaces utilizing recirculated air achieve the air cleaning performance level of a MERV 13 filter. Achieving the MERV 13 performance rating can be done so using equivalently effective air cleaners. Using equivalent outdoor air calculations (i.e. an additive equivalent outdoor air rate which includes the effects of outdoor air, filtration and/or air cleaners) ensure that necessary outdoor air levels are being met.

The *Harvard/ UC Boulder Portable Air Cleaner Calculator for Schools* recommends a goal of an equivalent of 5 eACH of clean supply air. This will result in the total air volume of a space being exchanged with equivalent clean air at a rate of five times per hour; however the effective air change rate is reliant upon air distribution effectiveness. For example, the typical design standard for classroom minimum ventilation (of outdoor air only; not the eACH including the effects of air cleaners) is around 3 ACH. There are many conditions that will impact the eACH of a classroom, such as existing filtration levels, that need to be identified to determine the existing eACH level. Note that ACH values are likely a good starting point for review, however, may not be a solid proxy of risk reduction in spaces with poor air distribution. Air cleaner configurations are important in large spaces with poor air distribution.

AIR CHANGE RATE GAUGE

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY

An example calculation of effective outside air changes per hour (obtained from the *ASHRAE Equivalent Outdoor Air Calculator*) can be found to the right:

OUTDOOR AIR

Increasing the outside ventilation air supply dilutes the concentration of airborne particulates in a space, including pollutants and infectious diseases. For the simple, steady state case (constant ventilation air flow rate and constant particulate generation rate), the concentration of infectious aerosol particles will be inversely proportional to the ventilation air flow rate (reference). This is shown graphically in the figure on the bottom right. This assumes that the concentration of the particulate(s) of interest is negligible in the outdoor air (one exception being carbon dioxide, which exists in the outdoor atmosphere at a level of roughly 400-500 ppm) and that the supply air is well mixed with air in the space. When these assumptions vary, the curve will be shifted accordingly.

In too many cases, buildings receive outside air flow rates below minimum code values (as established by ASHRAE 62.1) or design requirements. Reasons for this include control issues, mechanical issues such as broken fan belts, disconnected dampers, duct leakage, broken linkages, deferred maintenance, or the desire to save energy.

Additionally, the air handling unit's supply and return fans may not be operating properly. They may be running at less than their design speed and not supplying enough air to the space. This can affect building pressurization and allow the spread of infectious aerosols since there is less dilution air.

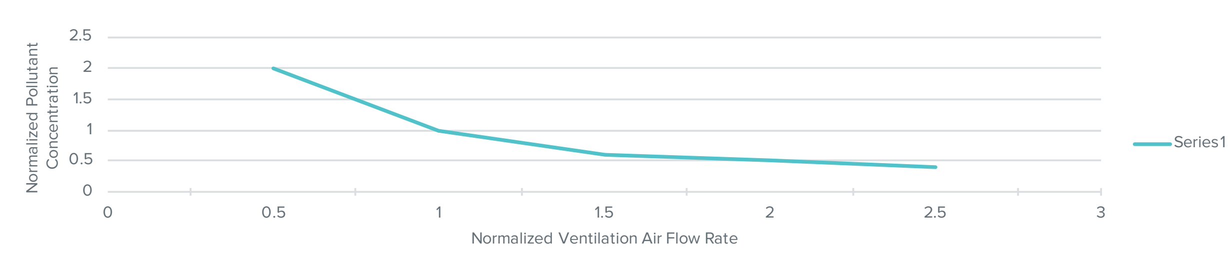
Foremost, ASHRAE recommends providing and maintaining minimum code required outside air ventilation rates to all spaces. *ASHRAE Standard 62.1* defines the minimum outside air requirements as a function of space type, size, and occupancy.

Example minimum outdoor air ACH rates are presented in *Section 2* of this guide for various higher education space types. These values are based on the ASHRAE default occupancy density levels (per *ASHRAE Standard 62.1-2016, Table 6-1*) and typical 10 ft. ceiling heights (10 ft. ceiling height was used as representative height for calculation purposes).

EQUIVALENT AIR CHANGE CALCULATION SAMPLE

Name of Space I AHU I Building	Units	Sample I AHU 1
Area	Sq Ft	14400
Average Ceiling Height	Ft	9
Volume	Cu Ft	129600
Total Supply Air	CFM	12500
Total Outdoor Air	CFM	1250
Supply Air ACH	ACH	5.79
Outdoor Air ACH	ACH	0.58
Central AHU Filter MERV Rating	MERV	13
UVC Single Pass Inactivation	%	90.00%
In Room Fan Hepa Filter	CADR	450
Number of In Room Fan HEPA Filters	Qty	2
Effective Air Changes Based on Technology		
ACH_OA	ACH	0.58
ACH_f	ACH	4.68
ACH_e,c	ACH	0.47
ACH_ir	ACH	0.42
Sub- Total Effective ACH	Ez	1.0
Total Effective ACH_e		6.15
Time Required to achieve Target Air Changes	Target Air Changes	3
Minutes	Min	29.26
Hours	Hours	0.49

GENERIC DILUTION CURVE



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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

To derive the airflow quantity, the following formula is used.

Airflow (CFM) = (# of Occupants * Rp) + (Square Footage * Ra)

Variables:

Rp: People Outdoor Air Rate (cfm/person-per ASHRAE 62.1)

Ra: Area Outdoor Air Rate (cfm/square foot-per ASHRAE 62.1)

Secondly, a combination of airborne exposure control options should be used to meet the desired exposure reduction target. This guidance allows for more energy efficient strategies, such as air cleaning and increased filtration, to assist in providing a clean air equivalent to what outside air alone would achieve.

ASHRAE recommends a combination of filters, air cleaners, and UVGI to achieve MERV 13 or better levels of performance for air recirculated by HVAC systems. (*ASHRAE Core Recommendations for Reducing Airborne Infectious Aerosol Exposure*)

Discussion of selecting a desired exposure reduction target in terms of air exchanges per hour (ACH) is identified in the *Desired Exposure Reduction section above*. The calculation for outside air ACH is presented below. This metric is used to quantify how many times an HVAC system can completely exchange the volume of air in a room with clean outside air.

ACH= (Supply air CFM * 60)/volume of space

Variables:

CFM: airflow, in units of cubic feet/minute

Volume: Room Volume (Length * Width * Height)

ASHRAE recommends that whenever a space is occupied, that equivalent clean air supply is provided per design occupancy levels.

PRE- OR POST- BUILDING OCCUPANCY AIR FLUSHING

ASHRAE recommends daily air flushing of occupied building spaces, either pre- or post-occupancy, for a duration sufficient to reduce the concentration of airborne infectious particles by 95%, which is equivalent to 3 air changes. The air flush should consist of a combination of strategies (outside air, filtration, air cleaning) that will achieve this 3 air change target. ASHRAE presents two methods to determine a sufficient duration:

- Operate systems at maximum capacity for a minimum of 2 hours pre- or post- building occupancy,[23] or
- Provide 3 air changes of equivalent outdoor air for a calculated timeframe. The calculation is as follows: $t = \frac{AC \cdot V}{60 \cdot OA_{EQ}}$

Variables:
t: time, (hours)
AC: Air Changes, 3
V: Room Volume

OA_{EQ}: Equivalent Outside Air

FILTRATION

ASHRAE recommends filtration with a MERV 13 or greater efficiency rating, preferably MERV 14, for HVAC systems that use recirculated air. Systems that use dedicated outside air do not require increased levels of filtration, however, terminal equipment served should have filtration efficiency increased to the extent possible for increased removal of contaminants at the local space level. It is critical to ensure proper airflow is maintained before adjusting filters, since a higher filter pressure drop, without making proper system adjustments, will typically reduce airflow. ASHRAE prescribes a very detailed methodology approach as part of their guidance document with regards to filter evaluation.[24]

Increasing MERV filtration levels is often the most feasible airborne transmission reduction strategy to implement. The following factors, which are provided by the ASHRAE Filtration and Disinfection guidance document,[25] determine overall filter effectiveness in removing particles.

[23] This method is assumed to be sufficient for most systems
[24] *ASHRAE Readiness, October 2020, pages 16-20*
[25] *ASHRAE filtration and disinfection guidance document-page 10*

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

Filter efficiency

- » Filter efficiency is the fraction of particles removed from the air stream by passing through the filter
- » Minimum Efficiency Reporting Values (MERV) identifies the efficiency of mechanical filters, with MERV ratings ranging from 1 to 16. The higher the MERV rating, the more effective the filter is in removing particles from the air stream (*ASHRAE Building Readiness* 03-16-2021, p36). MERV ratings establish the required efficiency over a wide range of particle sizes, with minimum efficiency established for particle ranges from 0.3 to 10 microns in diameter. Consult with *ASHRAE Applications Handbook* (Chapter 8-table 7, 2019) for minimum filtration efficiency for various applications in non-epidemic situations. The table to the right shows the efficiency percentages of various particle sizes for each MERV rating level (per *ASHRAE 52.2-table 12.1*).
- » High Efficiency Particulate Air (HEPA) filters are even more efficient than MERV filters, providing at least 99.97% efficiency at filtering 0.3 micron particles. HEPA filters are preferred from an infection control perspective, but typically cannot be retrofitted into most commercial HVAC systems due to space constraints and high pressure drops.
- » Electrostatic filters are mechanical filters that contain static electrical charges, which increase particle removal; this charge will dissipate over time. Filter effectiveness tested without the electrostatic charge is represented as a MERV-A value which can be found in *ASHRAE Standard 52.2-2017*.
- » Electronic filters are mechanical filters that utilize a high-voltage electric charge to charge particles (as opposed to using static electricity as in electrostatic filters).

Velocity of air through the filter

- » As MERV ratings increase, pressure drop rates through the filters generally decrease. For a constant speed fan in a system than cannot be rebalanced, increasing the MERV rating generally decreases the system air flow. In a variable speed system, the rated face velocity does not change. Prior to upgrading filter ratings, ensure the HVAC systems can handle the reduced air flow. If possible, select a proper filter to get close to performance of existing filter in order to reduce impact.

Size and number of particles traveling through the filter

- » The most penetrating particles for typical mechanical filters are around 0.3 µm in diameter. Mechanical filters are most efficient at capturing particle sizes smaller and larger than this. Refer to *Section 2* for a typical filter curve.

Location of the filter in the HVAC system, typically located before the cooling coil.

TABLE 12-1 MINIMUM EFFICIENCY REPORTING VALUE (MERV) PARAMETERS

STANDARD 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	RANGE 1 0.30 to 1.0	RANGE 2 cfm / ft^2	RANGE 3 3.0 to 10.0	AVERAGE ARRESTANCE, %
1	N/A	N/A	$E_3 < 20$	Aavg < 65
2	N/A	N/A	$E_3 < 20$	65 ≤ Aavg
3	N/A	N/A	$E_3 < 20$	70 ≤ Aavg
4	N/A	N/A	$E_3 < 20$	75 ≤ Aavg
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

Operation, maintenance, and cleanliness of filters and electronic filter components (if applicable). Conduct an integrity test of filter to ensure proper installation; proper sealing of frame is necessary to avoid any leakage.[26]

For proper functionality, filters must be installed with a tight seal, in dry environments, and per manufactures specifications. As the pictures to the right exhibit, filters not correctly installed in their frame or filters which have been blown out because of high pressure drop will allow air to bypass the filters and therefore, will not perform.

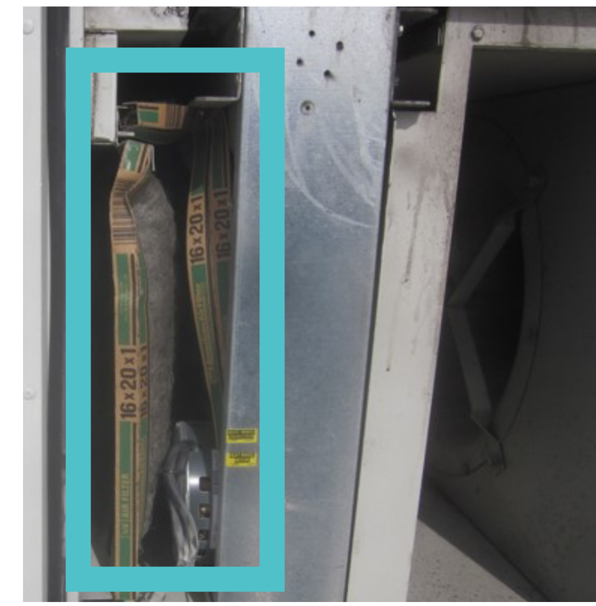
- » For electrostatic air filters, silicone buildup should be wiped from the wires to prevent decreased efficiency.
- » For electronic filters, ensure that particle buildup is wiped off periodically and electrical system is free of corrosion.
- » Before filter change out, consult with your filter vendor and/or check dimensions, to ensure that new filters will fit properly within frame.[27]
- » Ensure proper velocity across the filter bank (typically 500 fpm) is maintained. Velocities that are too high can lead to filter casing caving, and/or high moisture levels (from bringing in snow and rain) which will quickly degrade the performance of the filter.
- » Ensure manufacture recommendations for filter change out is built into maintenance schedules, and annual budgets. Note that higher MERV filters typically need to be changed out more often (depending on clean and dirty pressure drops).
- » Augment the BMS to monitor filter pressure drop, if possible
- » Store filters in a dry area (palettes preferable to avoid ground moisture).
- » Incorporate filter maintenance into standard operating procedures (SOP)

[26] For reference, a MERV 15 filter with a 0.4” gap around frame performs equivalent to a MERV 8 filter

[27] When changing out filters, be sure to wear mask and stand up-stream of filter as mitigate breathing of air after filter has been agitated. Immediately bag filters after removal for proper disposal.

POORLY INSTALLED FILTERS

Destroyed 2x2 filter stuck in heat wheel



Deformed 2x2 filters & needlessly stacked filters

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

DEMAND CONTROL VENTILATION

Demand Control Ventilation (DCV) is an energy conservation strategy that modulates the supply of outdoor air to reduce outdoor air volumes when occupant density is low and to ensure there is a proper quantity of outdoor air when spaces are occupied. CO_2 concentration is used as a proxy to indicate the number of occupants in a space as we all exhale CO_2 as a function of our activities.

Under normal circumstances (i.e., non-pandemic scenarios), ASHRAE recommends maintaining CO_2 concentration of approximately 700 ppm greater (*ASHRAE Standard 62.1 Normative Appendix D*) than the ambient outside air levels (typically between 350-500 ppm). For epidemic operating conditions, ASHRAE recommends temporarily disabling the DCV control sequence for systems/ adjusting the setpoints to be at or near ambient outdoor CO_2 levels. Systems incorporating diversity of people in the space into sizing may require DCV to maintain ventilation to occupied spaces.

AIR DISTRIBUTION

Airflow within spaces should be optimized to provide effective distribution of outdoor air in a manner that will not cause strong air current or direct airflow to pass by person-to-person.

To achieve this, review airflow levels and patterns in occupied spaces to ensure airflow is not impeded, and/or short circuiting from supply to return without given proper airflow through space.

One commonly observed deficiency with regards to airflow includes bathroom exhaust fans that are turned off. This reduces the ventilation in the space and affects the pressurization of the bathroom. Because the act of flushing a toilet can generate infectious aerosols, the operation of the bathroom exhaust fans is critical to prevent the flow of aerosols from the bathroom to adjacent spaces. Therefore, bathrooms should be kept at a negative pressure to reduce the flow of air from the bathroom to the surrounding areas. Also, ASHRAE recommends consideration of fixed toilet tops to avoid unintended spread. It is also beneficial to inspect the locations of the toilet exhaust. Proper location of exhaust diffuser(s) (as close to directly over the toilets as possible) can ensure that aerosolized particles are not traveling unnecessarily far distance throughout the room. Although the reconfiguration of the HVAC system and the diffusers themselves may prove difficult and costly, it is beneficial to inspect these toilet rooms and their HVAC layout.

To calculate the ACH of total airflow in a space, the same formula that was used to calculate outside ACH can be used. The only difference being that the CFM should represent the total airflow of the space (as opposed to the outside airflow). ACH is reliant upon the air distribution effectiveness; which is a measure of how effectively the supply air is used to maintain acceptable air quality. Using the *ASHRAE Equivalent Outdoor Air Calulator*, modifications to the air distribution effectiveness can be made in order to see how ACH varies with changing effectiveness factors.

AIR TO AIR ENERGY RECOVERY VENTILATION (ERV)

Many building HVAC systems utilize Energy Recovery Ventilation (ERV) or heat recovery systems to temper outdoor air using sensible and latent energy from building exhaust.

Some ERVs utilize separate coils in outdoor air and exhaust ducts, with heat transferred via fluids pumped between the coils. Known as runaround loops, these systems provide a safe separation between exhaust and outdoor air supply, and the risk of cross contamination is minimal.

Heat wheel ERVs utilize a wheel-shaped media that rotates between immediately adjacent supply and return ducts, with thermal energy transferred as the wheel rotates from the hot duct (which is typically building return air) to the cold (which is typically largely composed of outdoor air). While highly efficient (capable of recovering latent and sensible heat), heat wheels do present opportunities for cross-contamination of exhaust air. Re-entrainment can be limited by ensuring a positive pressure differential between the outdoor air and exhaust air ducts.

ASHRAE Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems has extensive discussion of ERVs.

Note that any ERV with co-located ducts or compartments contain some level of vulnerability to air leakage between air streams. This can occur at the exchanger itself, or between the supply and return ducts where leaks may be present. Refer to the *ASHRAE HVAC Systems and Equipment Handbook, Chapter 26 "Air-to-Air Energy Recovery Equipment"* for full descriptions of energy recovery technologies.

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

The Air to Air Leakage Guidance figure on the bottom right demonstrates the importance of pressure relationship in avoiding cross contamination. The leaving static pressure (SP2) of the supply air (upper air stream) should be at least 0.5 in w.g. greater than the entering return air (SP3). This pressure relationship will help result in airstream "pushing" from the cleaner outdoor air to the "dirtier" return side.

ASHRAE's position is that well-designed and well-maintained air-to-air energy recovery systems should remain operating in residences, commercial buildings and medical facilities during an epidemic. Refer to the *ASHRAE Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems* for information on well designed/maintained energy recovery equipment. This is because they believe for occupants to be able to combat infectious aerosols it is important to maintain normal outside airflow rates with proper temperature and humidity set points, at a minimum.

ASHRAE defines "well-designed" as:

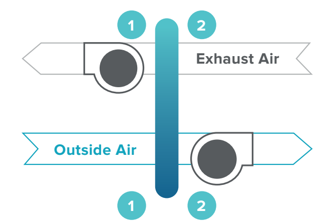
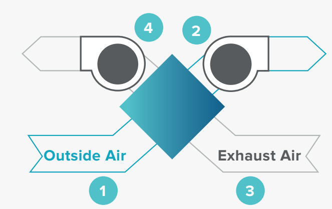
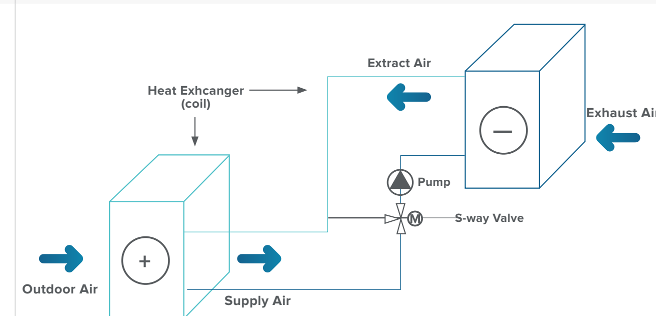
- » Correct location of supply and exhaust fans to allow for pressure control at the exchanger
- » Correct sizing of ERV for appropriate velocity and pressure drop
- » Correct seals or purges exist (or are specified) for the application

ASHRAE defines "well-maintained" as:

- » Systems that were initially installed, set-up and tested and balanced correctly
- » Systems that receive proper maintenance, per manufacturer's requirements

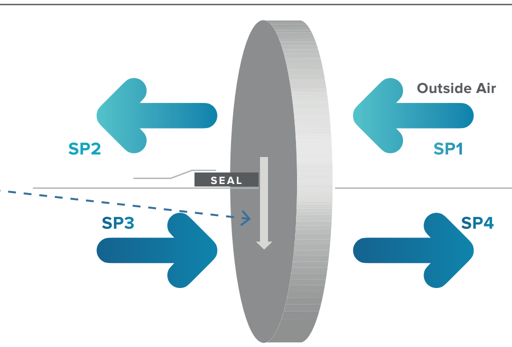
However, when an outbreak is expected or known to have occurred, ASHRAE recommends inspecting the system for proper operation and condition to evaluate the possible likelihood of the system contributing to contamination of the air supply.

ENERGY RECOVERY TECHNOLOGIES

Technology	Technology Diagram	Cross Contamination Possibility
Energy Wheels		Very possible, with imprlandomer design, maintenance, or operation
Plate Exchangers & Heat Pipes		Limited, unless housing or plate is split and/or failure of housing
Run-around Coil Loops		Not possible, unless coils are adjacent (i.e., supply and return airflow pathways are next to each other.)

AIR TO AIR-LEAKAGE GUIDANCE

SEAL LEAKAGE GOING IN PROPER DIRECTION: With proper system pressures seal leakage will go from the supply side (clean) to the exhaust side (dirty) airstream



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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

RE-ENTRAINMENT ISSUES

Prevention of re-entrainment of contaminants from the exhaust of a building is required by code but may be present in some installations. Although re-entrainment of contaminants from the exhaust of a building to a fresh air "receptor" (ex, outdoor air intake, open window, etc.) can be a concern if they are in close proximity to each other, ASHRAE does not highlight this as a major area of concern "for buildings that are not intentionally having COVID-19 positive people in the building or spaces."[28] Although there is a very low percentage of re-entrainment being a transmission route of infectious aerosols, ASHRAE recommends this issue be checked.

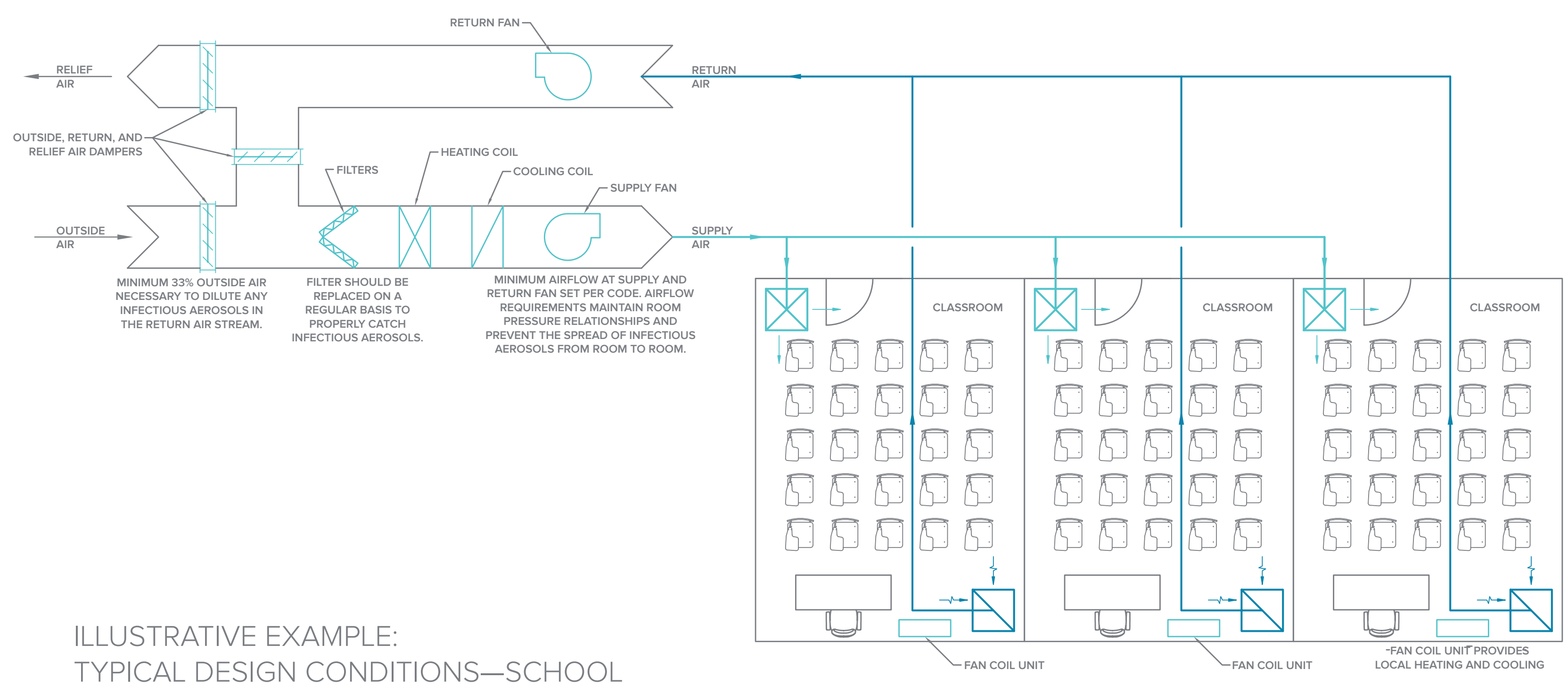
The diagram on the right illustrates some of these issues.

Refer to the *ASHRAE Exhaust Re-Entrainment Guide*[29] for more detailed guidance on how to determine the likelihood of re-entrainment risk, the total dilution target, and detailed risk assessment process strategies.

AIR CLEANING STRATEGIES

Supplemental technologies such as Ultraviolet Germicidal Irradiation (UVGI) and portable HEPA air cleaners can be used to improve indoor air quality. Note that these technologies should be accompanied by other strategies, including outside air and MERV 13 or higher rated filters in central recirculating HVAC systems. Other air cleaning technologies in the market, such as bipolar ionization, vaporized hydrogen peroxide (VHP), ozone, UVGI using LED lighting, and other emerging technologies should be

TYPICAL AHU LAYOUT



ILLUSTRATIVE EXAMPLE:
TYPICAL DESIGN CONDITIONS—SCHOOL

NOTES (Fillable):

[28] *ASHRAE Building Readiness guideline*, page 21
[29] *ASHRAE Exhaust re-entrainment guide* for evaluation methodology

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

evaluated carefully before being implemented. ASHRAE recommends only using air cleaners that have clear evidence to support its effectiveness and safety for their intended use and operation.

As previously mentioned, air cleaning devices can be factored into achieving the *desired exposure* reduction levels in spaces. The following formula can be used to calculate the equivalent ACH of an air cleaning device:

Equivalent ACH = (CADR * 60) / (Square Footage of Space * Ceiling Height)

Where: CADR = airflow rate * removal efficiency

Note that if a UVGI device is installed in an AHU after the filter, the impact of the filter must be removed prior to determining the CADR of the UVGI device (i.e. the filter and UVGI device are essentially acting as air cleaning devices in series).

The Clean Air Delivery Rate (CADR) is a rating of combined filter efficiency and the amount of air that passes through the system. The CADR is typically identified on portable air cleaning devices. For central system air cleaning applications where a CADR is not available, the following can be used to determine the CADR[30]:

» If the airflow through the device is known, use the following table to get the efficiency, then use the following formula:

CADR = airflow rate * filter efficiency

FILTER COSTS, PRESSURE DROP, LIFESPAN & EFFICIENCY

Filter	Size	Approximate Cost	Typical Initial Pressure Drop (in.w.c.)	Typical Final Pressure Drop (in.w.c.)	Typical Average Pressure Drop (in.w.c.)	Typical Filter Lifespan (months)	Typical Filter Efficiency (%)
MERV 4	24x24x2	$2	0.088	0.502	0.293	3	11.0%
MERV 7	24x24x2	$4	0.289	0.599	0.446	3	44.0%
MERV 11	24x24x2	$7	0.326	0.751	0.567	4	72.0%
MERV 13	24x24x2	$11	0.362	0.751	0.579	4	87.0%
MERV 14	24x24x12	$50	0.510	1.001	0.756	12	89.0%
MERV 15	24x24x12	$90	0.281	1.001	0.639	12	90.0%
MERV 16	24x24x12	$125	0.261	1.001	0.631	12	95.0%
HEPA	24x24x12	$150	1.001	2.001	1.503	12	99.0%

Reference: HVAC filtration and the Wells-Riley approach to assessing risks of infectious airborne diseases Table 10

* Pressure drop for MERV 11 and MERV 13 reference: Marwa Zaatari, Atila Novoselac, Jeffrey Siegel. 2014. The relationship between filter pressure drop, indoor air quality, and energy consumption in rooftop HVAC units. Building and Environment Volume 73, March 2014, Pages 151-161

[30] *EnVerid COVID-19 Energy Estimator Tool*

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

- For UVGI devices, you can use a proxy CADR by using the following formula:

  CADR = Airflow rate (which passes by UV lamp) * reported efficiency

  Be sure to consider residence time, the output loss if the UV lights are placed after the cooling coil (cold environment), and lamp depreciation. Note that if the UVGI device is installed after the filter, the effect of the filter on cleaning the air must be removed prior to determining the CADR of the device (the filter and the UVGI device are essentially in series).

UVGI

ASHRAE supports the use of ultraviolet germicidal irradiation as an acceptable air cleaning technology. Of course, air cleaning technologies should only be utilized once proper filtration and ventilation rates are in place. UVGI uses UV light in the C band (UV-C) which has a wavelength range of 200 – 280 nanometers. All wavelengths in the UV spectrum are capable of inactivating viral, bacterial and fungal organisms in water, air and on surfaces so they are unable to replicate and potentially cause disease. The UV-C wavelength, however, provides the highest germicidal effect radiating energy at 253.7 – 254 nanometers, with 265 nanometers being the optimal wavelength.[31]

There are generally three air treatment methods for applying ultraviolet:

- In-AHU or In-Duct
- Upper room
- Portable air cleaners (which may also include HEPA filters and other air cleaning technologies, such as bi-polar ionization)

Each of these technologies are discussed on the subsequent pages.

Note there are published safety guidelines for UV-C lighting which should be considered wherever UVGI systems are applied. Specifically, UV-C can cause eye and skin damage (that typically resolves completely within 1 – 2 days of exposure), therefore precautions to avoid direct contact is important. Maintenance workers should receive special training before working on such systems.

[31] https://www.ashrae.org/file%20library/technical%20resources/covid-19/i-p_s16_ch17.pdf

IN-AHU AND IN-DUCT UVGI

Using banks of UV-C lamps in air handing units to treat the air requires high dosing to inactivate microorganisms as they pass through the irradiation zone (aka "on the fly"). Due to the high air velocity, there is typically limited exposure time. Based on a typical system design airflow of 500 feet per minute (fpm), an in-unit UVGI system would need a minimum irradiance zone of two feet with an exposure time of 0.25 seconds. ASHRAE recommends that in-unit UVGI systems should be accompanied by mechanical filtration to enhance the overall air cleaning. Filters are required by all ASHRAE ventilation standards in order to effectively remove particulate matter from the air.

In-unit UVGI applications should only be considered for virus removal in HVAC systems that use recirculated air, therefore it is not applicable to systems using 100% outdoor air units.

Work with a qualified UVGI professional to properly size and place the system for effective air treatment (to meet the desired target eACH in conjunction with other solutions such as filtration). They can also assist in ensuring there's enough room in the system to accommodate the size of the system needed. Please note general "rules of thumb" for consideration-see below.

- Very effective in inactivating viruses, bacteria, mold, etc.
- Deactivates virus by disrupting structure of nucleic acids and proteins.
- Mature technology as cleaning agent (commonly used in new hospital construction as coil disinfectant).
- Can retrofit to existing air handling units, if space allows; one advantage being a low pressure drop
- Reasonably priced. For a 20,000-cfm unit, figure approximately $ 1,000 in material cost.
- Systems typically designed for 500 fpm-can accommodate higher velocity with installation modifications
- Minimum target of 1,500 mJ/cm^2
- Minimum irradiance zone of 2 feet
- Minimum UV exposure time of 0.25 seconds

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

When considering an in-unit UVGI system, a total cost impact evaluation should be conducted including equipment, installation, and ongoing maintenance and energy costs.

UPPER ROOM UVGI

Upper room UVGI as an air treatment technology has a long history (dating back to the 1930s), with the first application for tuberculosis, measles, and mumps control.[32] The technology, which is typically located within the room of concern (at a height of 7' and above), relies on air currents to lift air up to the disinfection zone where pathogens will be neutralized, and the air will be recirculated in the space.

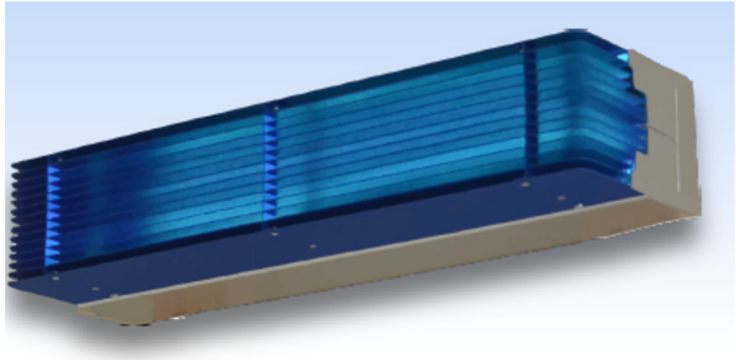
Key features of this technology include:

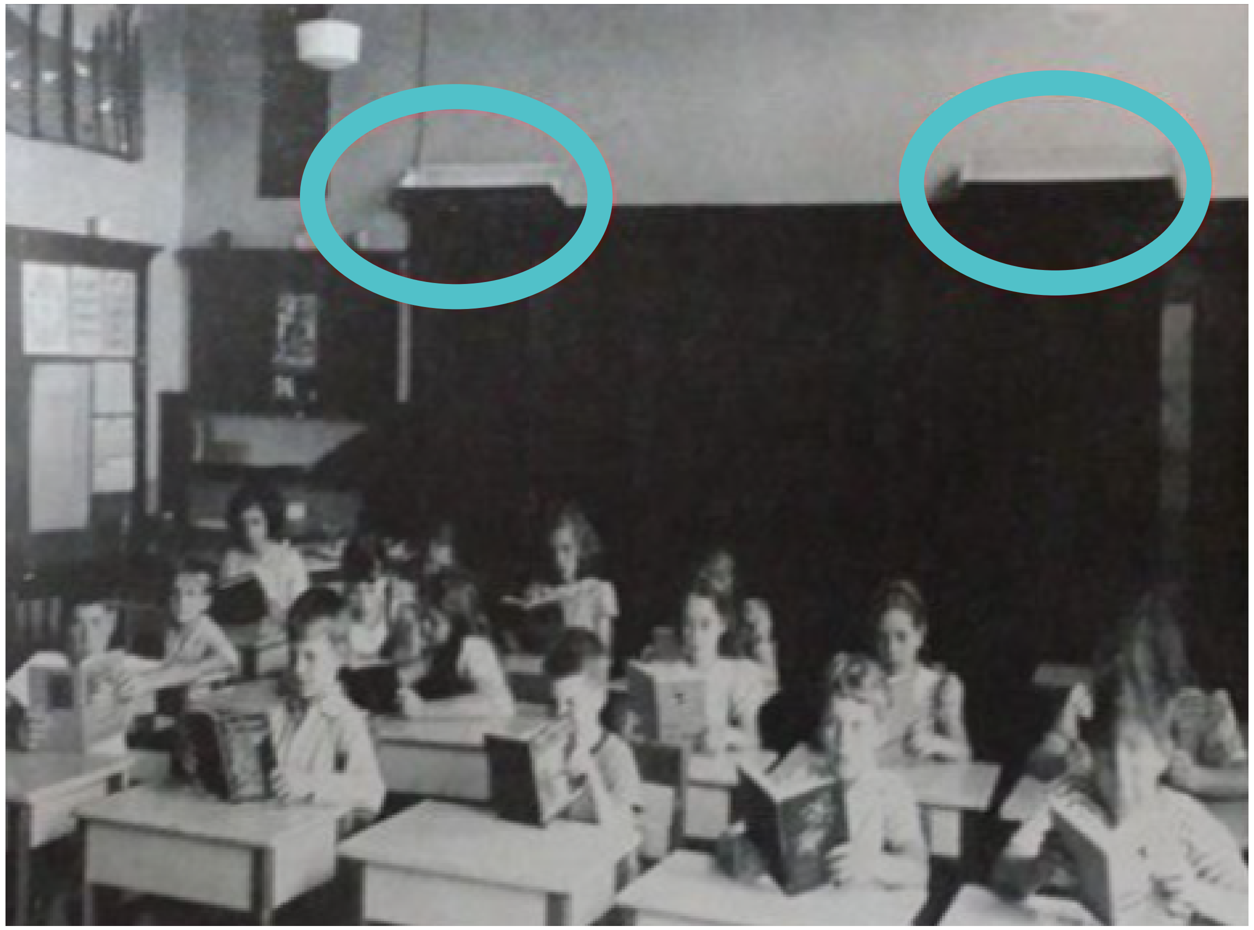
- Applicable when there is little or no mechanical ventilation
- Typically installed in spaces with high occupant density and other high risk spaces
- Requires low reflectivity of walls and ceilings to prevent the UV rays from reaching occupants in the space
- The ventilation system should be set to maximize air mixing in the space for the most effective results. Supplement use of fans to circulate air in the space can be used if the ventilation is insufficient.
- Units should be selected based on room size and available mounting locations
- Cost of fixtures and increased energy usage (rule of thumb is 12 Watts/square feet-based on vendor quote)

Note that upper room UVGI can be expensive. While every case is different, recent studies have shown that UVGI can be approximately 10x more expensive than airside UV-C.

[32] From W.F. Wells, M.W. Wells and T.S. Wilder "The Environmental Control of Epidemic Contagion: I. An Epidemiologic Study of Radiant Disinfection of Air in Day Schools

UVGI LIGHTING





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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

PORTABLE UVGI

There are several types of portable UVGI cleaners. Whole room devices are typically used for surface decontamination. Whole room technologies are not safe to operate when spaces are occupied as they beam the light throughout the space.

There are also portable UVGI units used for the purpose of air cleaning. These units can be placed in a space and used when occupied as the UV lighting is contained within the unit. There is a fan in the unit that draws air through the device providing direct disinfection of air. These units are typically accompanied by HEPA filtration and potentially other auxiliary technologies (e.g., bi-polar ionization).

PORTABLE HEPA FILTRATION

Portable HEPA filtration devices function similarly to the portable UVGI systems designed for air treatment, as described above. These systems typically draw air through them using a fan and infectious particles are captured by the internal HEPA filter. HEPA filters provide a higher level of filtration efficiency (at least 99.97%) as compared to a high rated MERV filter. Manufacture recommendations for operation and maintenance should be reviewed and followed. Furthermore, although combination HEPA & UVGI units go above and beyond the recommended strategy as put forth by ASHRAE, there are portable HEPA filtration units that include UVGI lamps as well.

EXAMPLE OF PORTABLE HEPA FILTER

The following should be considered for portable units:

- Safety: Ensure that there are no trip hazards due to cords being loose, etc.
- If possible, wall mounted units are preferable to avoid trip hazard. Although wall mounted may not be the ideal location for effectiveness, consideration must be taken to avoid any potential hazards.
- Units typically operate off of 120 V power, which makes them convenient. Proximity to grounded electrical outlet is preferred to minimize trip hazard.
- Noise can be a concern. To maximize benefits, the fan should be operated at full speed (see chart on the following page which demonstrates representative performance of a HEPA filtration unit as a function of air speed). Units should be tested before applying to ensure noise levels are not objectionable.
- Air distribution patterns of units need to be considered both independently and with respect to room HVAC distribution – strong currents of air (even clean air being distributed from the unit) must be avoided in the space, particularly when blowing over space occupants and toward others.
- Manufacture recommendations for square footage coverage should be strictly adhered too.
- Consideration of "smart outlets" should be considered to manage energy usage. There are several brands of UL listed adapters which can be tied to cell phones with programming schedules to limit energy usage.
- Ensure units are "true HEPA rated."
- Portable units are rated by the Association of Home Appliance Manufactures for CADR (for units capable of servings up to approximately 700 square feet).
- Filters typically need to be changed at some interval. Most units we are familiar with recommend changing out filters at 4,000 hours. This maintenance should be built into maintenance routines as well as consideration of whether or not the filters for the specific types of units are readily available (i.e. standard sizes/types) or if there is a proprietary filter that is needed.

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

The chart on the right shows the test results of a HEPA filter (installed for college classrooms-testing performed by Guth DeConzo). The test data shows that the performance at 100% fan speed (72% particle reduction) is much preferred to low speed, 33% fan speed (16 % particle reduction). This performance disparity emphasizes the need for operating the unit at high speed, which results in higher noise levels.

TEMPERATURE AND RELATIVE HUMIDITY

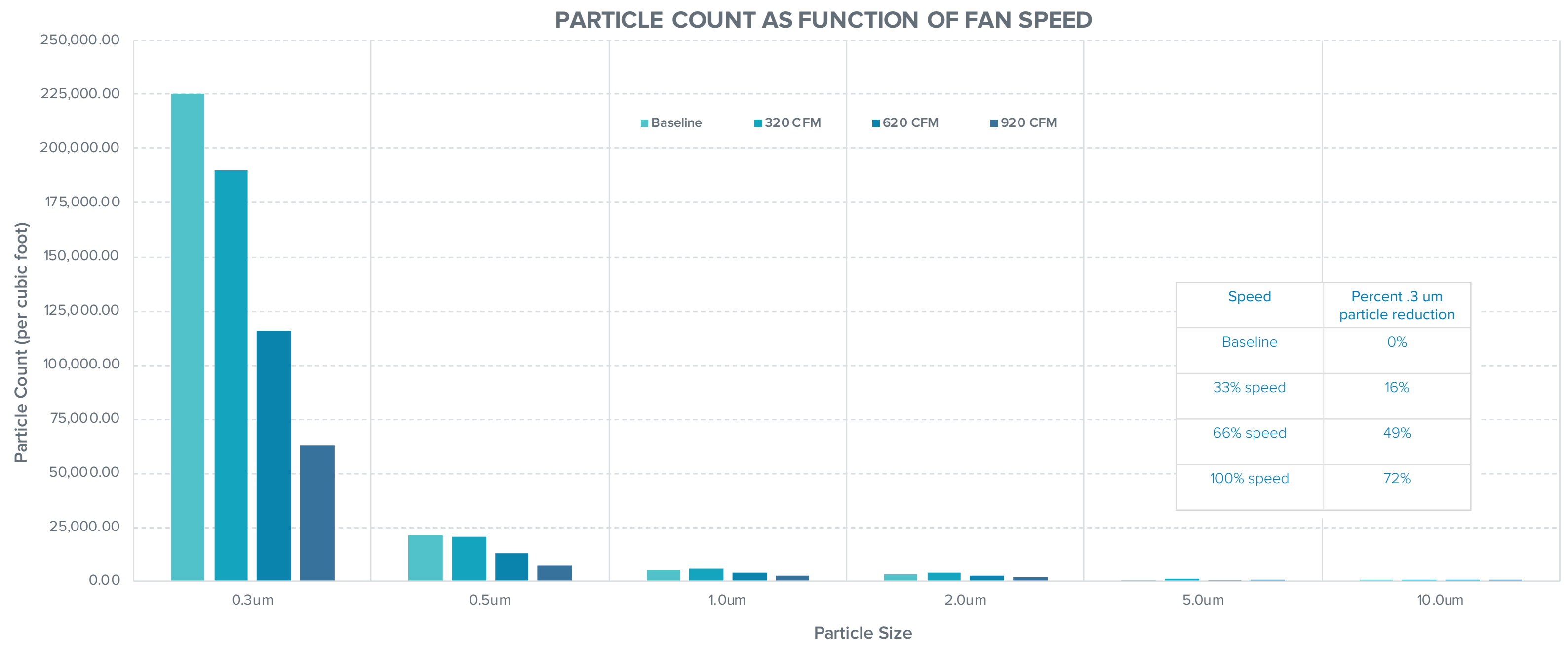
ASHRAE recommends maintaining design temperature and relative humidity (RH) set points. (*ASHRAE Building Readiness 03-16-2021*)

ASHRAE has also identified that "research indicates that maintaining the space relative humidity between 40% and 60% decreases the bio-burden of infectious particles in the space and decreases the infectivity of many viruses in the air" (*ASHRAE Building Readiness 03-16-2021 p17*).

For the NYS winter environment, maintaining a desired relative humidity of 40-60% RH is very difficult to accomplish. Most buildings, absent health care environments, labs and other specialties, were not designed with a central humidification system. While retrofitting buildings with a centralized humidification system is possible, the following concerns should be considered.

» Constructability concerns: Adding central humidification, either at AHU level or zone level, will typically require location of space for humidification manifold. This location for the manifold will typically be rather bulky, since

IN-ROOM HEPA FILTRATION - PARTICLE REDUCTIONS



NOTES (Fillable):

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

humidification systems will typically require a maximum velocity of 500 fpm, which will require larger ductwork than what is typical.

- Cost concerns: Central humidification is generally expensive, both from a first cost and operating cost perspective.
- Water treatment needs to be provided.
- Humidification systems will not work in the long term without proper maintenance and attention.
- An analysis needs to be conducted with regards to the building envelope (potential for condensation and mold development). Be sure to not solve one problem with the addition of another problem.
- The increased energy and water usage needs to be considered. While energy use varies as a function of the system selected (and a function of local energy rates), the increase in operating cost needs to be evaluated and included in future budgets. When increasing outdoor air/ventilation rates in cold climates, humidification rates will proportionally increase as well.
- Portable humidifiers are an option for local high risk spaces (e.g., nurses office) and also where it is deemed cost prohibitive for a centralized system. For portable units, the provision of makeup water and monitoring of local conditions needs to be included. Note that without provision of automatic makeup water, manually filling up the tank every day or other day should be expected-not an easy maintenance task to keep up on for our long dry winters.

If misapplied, humidifiers can create condensation issues or contribute to mold growth. Criteria to consider when placing local humidification unit in a space includes:

- Make-up water must be monitored and added by staff as necessary
- Windows and building envelope should be tight to avoid condensation and moisture issues with the thermal envelope
- Any condensation forming on any surfaces should be carefully monitored. If left unattended, it can result in mold formation. RH set points should be lowered just below the point at which condensation forms on exterior surfaces to prevent mold formation. This will vary with outside air temperature.
- Either a BMS or local data loggers should be installed to monitor relative humidity. An assessment of the envelope should be considered to monitor the maximum relative humidity, and monitoring used to track and trend local conditions.

Although humidification in general is considered a best practice for indoor air quality, maintenance and realistic application of any new installation must be considered. An engineering analysis is recommended before this option is pursued.

BUILDING MANAGEMENT SYSTEM (BMS) OPTIONS

ASHRAE recommends leveraging the BMS to improve infection control strategies in the following ways:

- Update sequence of operations where appropriate. See *Section 4- Develop Improvements* for additional guidance.
- Adjust alarm parameters via BMS algorithms to account for improved IAQ setpoints and sequences. Alarm triggers should account for the following poor IAQ events:
  - Low total discharge airflow
  - Low outdoor airflow
  - Relative humidity outside the recommended achievable range (too low or too high)
  - High filter differential pressure (dirty filter – required replacement)
  - Low filter differential pressure (loss of filter or poor installation)
- Consider including automated responses to allow for “push of the button” switching between pre-epidemic and epidemic-in-place sequence modes. Alarm parameters may need to be adjusted for the various modes.

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES BY CATEGORY CONT.

As a best practice, install combination carbon dioxide (CO_2), particle count, VOC and relative humidity sensors in high risk spaces that can be connected and added to the existing BMS.[33] Adding control points and a sequence of operations tied to the combination sensors can modulate dampers, airflows, and humidification to meet IAQ parameters under a ‘high risk’ time period. Please refer to *ASHRAE Guideline 36-2018 High-Performance Sequences of Operation* for HVAC Systems for best practices.

BUILDINGS WITHOUT BMS

For buildings without BMS systems in place, portable data loggers can be used to monitor space conditions. Loggers can be as simple as standalone loggers, or loggers which can be tied into Bluetooth/wireless applications. Data points to be considered are:

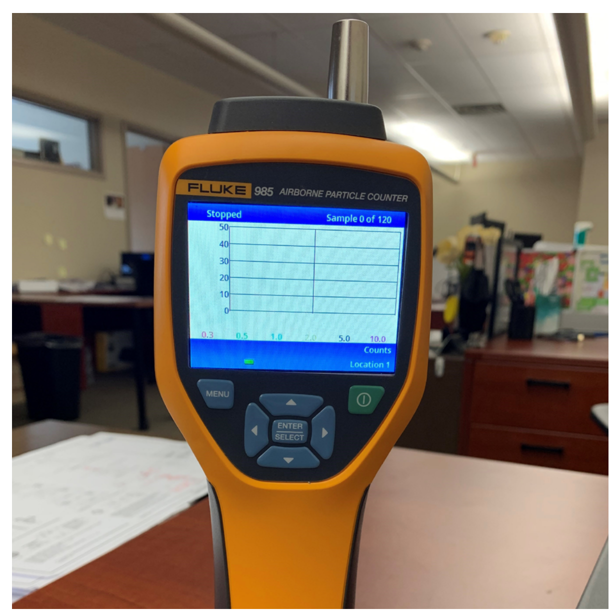
- Particle Counter (typically $ 5,000 per test kit): Particle count can be used as a proxy for infectious diseases and can indicate how well filtration and UVGI may be working.
- CO_2 monitoring (typically about $ 300 per sensor) indicates if space is getting proper outdoor air ventilation.
- Relative Humidity (typically about $ 100 per logger)
- Occupancy (typically about $ 150 per logger): provides data on how frequently a space is occupied

A sample of common data loggers is shown to the right:

COMMON DATA LOGGERS

CO_2 Logger

Ion Counter



Particle Counter

Temperature & Relative Humidity Logger

[33] CO_2 measurements are only a proxy for outdoor air levels and are not a good proxy for viral risk/infectious aerosol potential as CO_2 measurements do not account for the effectiveness of filters and UVGI devices, nor will CO_2 levels vary based on the number of infected occupants. TVOCs/PM2.5 measurements will indicate filter impact but will not account for UVGI impact. SARS-CoV-2 measurement devices are available but are extremely expensive. Use of combination IAQ sensors are effective in showing trends over time to indicate outliers that need addressing.

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES FOR SPECIAL SITUATIONS CONT.

SPECIAL SITUATIONS
ASHRAE documents special considerations for high risk and higher education-specific buildings and spaces.

NOTES (Fillable):

Reduced Occupancy & Closures

Relaxed Temperature & Humidity
Operate the HVAC systems in unoccupied modes using relaxed temperature and humidity set points to help reduce energy consumption and cost

Laboratories

Ventilation
Verify AHU one-pass capabilities and set to 100% outside air or the maximum outside air capable for lab operating requirements Verify proper airflow patterns through the use of a smoke test and ensure convection loops and well mixed air are present

Classroom

Air Cleaning
Consider introducing terminal or portable HEPA and/or UVGI machines for additional air cleaning benefits

Restroom, Locker & Laundry Room Exhaust:

Exhaust Airflows
Verify exhaust airflows are at a minimum 1.0 cfm/square foot

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES FOR SPECIAL SITUATIONS CONT.

NOTES (Fillable):

Athletic Facilities

Ventilation	Air Cleaning
Verify locker room exhaust flows achieve minimum rates according to *ASHRAE Standard 62.1* Avoid use of locker rooms, but if necessary, keep locker room under negative pressure by increasing airflow Increase outside air as much as HVAC equipment will allow	Consider introducing terminal or portable HEPA and/or UVGI machines for additional air cleaning benefits in high risk spaces

Dormitory/ Residence Halls

Ventilation	Air Cleaning
Verify outside air rates are greater than 0.16 cfm/square foot Increase outside air as much as HVAC equipment will allow Ensure proper airflow patterns	Consider introducing terminal or portable HEPA and/or UVGI machines for additional air cleaning benefits in high risk spaces

Large Assembly

Ventilation	Exhaust Airflow	Air Cleaning
Increase outside air as much as HVAC equipment will allow Provide additional outdoor air and/or mobile HEPA Filtration units in rehearsal and green rooms	Verify exhaust airflows at all concession stands are at a minimum of 0.7 cfm/square foot	Consider introducing terminal or portable HEPA and/or UVGI machines for additional air cleaning benefits in high risk spaces

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EPIDEMIC HVAC MITIGATION STRATEGIES

HVAC MITIGATION STRATEGIES FOR SPECIAL SITUATIONS CONT.

NOTES (Fillable):

Student Health

Create a temporary isolation and waiting room and operate them per the isolation mode parameters listed below, as possible.[34] Some recommendations may require significant design and capital improvements.

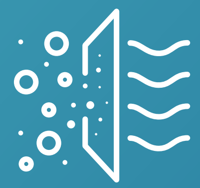
Ventilation	BMS	Filtration	Temperature/ Humidity	Air Cleaning
Operate as an isolation room (Follow *ASHRAE 170* and *2019 Handbook Chapter 9*)	Create Isolation Mode (Following *ASHRAE 170* and *2019 Handbook Chapter 9* guidance) and Normal Mode sequences of operation	Follow *ASHRAE 170, table 6.4* filtration guidelines for a protective environment (PE) – 2 filter banks, MERV 7 and HEPA (or MERV for systems that can't handle HEPA)	Per design setpoints	Consider introducing terminal or portable HEPA and/or UVGI machines for additional air cleaning benefits in high risk spaces.
Operate at 6 ACH during occupied times				
Use a dedicated HVAC system, capable of 100% OA				
Follow CDC guidelines for supply air and return air paths, if possible Do not mix isolation room air with any other spaces Directly exhaust isolation rooms Follow design guidelines for location of outdoor air intakes and exhaust air from exhaust fans				

[34] *ASHRAE Schools & Universities 10-7-2020 p20-21*

EPIDEMIC HVAC MITIGATION STRATEGIES TAKEAWAYS

1
VENTILATION, FILTRATION, & AIR CLEANING

Ventilation, filtration, and air cleaning are the three primary variables of an HVAC system that impact IAQ. In addition, relative humidity, the building management system, and ongoing commissioning are important tools to utilize in improving IAQ.



2
IMPROVE IAQ REGULARLY

To improve IAQ on a regular basis, O&M personnel can utilize the *System Evaluation checklist in Section 6*.

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SECTION 6

HVAC SYSTEMS EVALUATION CHECKLIST

06

HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS

These checklists serve as a guide to evaluating the existing conditions and potential for system modifications in HVAC systems that can impact the IAQ of a building. The checklist covers items that will reveal:

» Proper system operation (per design conditions or current operational strategies)

» Issues that should be repaired (examples include loose fan belts, disconnected actuators, frozen dampers, impediments to airflow and/or damper operation, incorrect outdoor air settings, etc.)

» Capability of system modification to align with ASHRAE's epidemic *HVAC mitigation strategies*. To effectively perform this objective, review the ASHRAE recommended mitigation strategies before conducting the system evaluation.

Note that although buildings require a multitude of systems for proper provision of HVAC, this checklist focuses on systems which directly affect indoor air quality. Indirect systems (e.g., chilled water systems, boiler systems, pumps, heat exchangers, etc.) should also be inspected for proper operation and for confirmation of up to date maintenance as part of this system evaluation. To ensure energy savings is maximized confirm that the proper water and air conditions are met for heat exchange devices.

While each of the items listed in the checklist is pertinent to review as part of systems evaluation, the ongoing frequency that each of the items should be re-evaluated is also indicated within this checklist. It should be expected that the HVAC system evaluation is likely to uncover issues that need to be addressed immediately since IAQ and general system deficiencies can develop over time. Although a system may have been designed and installed correctly, unforeseen conditions do occur that may change the operation of systems over time, in addition to other issues that can derail the best IAQ practices. Depending on the complexity of the campus and known issues, several items may be identified during the HVAC System evaluation.

ASHRAE recommends that building systems are evaluated by a qualified commissioning provider, TAB agent/firm and design professional to ensure that the modifications for pandemic safety do not create additional issues, such as the ability of systems to maintain space temperature and humidity conditions. The decision to enlist the service of one of these professionals depends on the experience level of campus staff to perform the evaluations presented in this checklist. The expectation of this guide is that the user will have a solid understanding of building system operations. Consideration of hiring a professional before making any system modifications may be prudent to ensure no unintended harm results from changes made.

For additional guidance on system evaluations, refer to *ASHRAE Standard 180-2018: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*.

For additional guidance on checking calibration, refer to *ASHRAE Guideline 11-2018: Field Testing of HVAC Control Components*.

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

AIR HANDLING UNITS & ROOFTOP UNITS

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Check dampers for proper condition of seals and linkages, settings, and actuation operation.	Clean, lubricate, repair, replace, or adjust as needed to ensure proper operation.	High	Semiannually	No
2	Ensure all spaces are getting an acceptable amount of outdoor air and total air ventilation.	Review measured outdoor airflow rates compared to *ASHRAE 62.1* (including VAV airflows in the space), and adjust as required. Review maximum and minimum flows to ensure system is delivering correct amount of OA	High	Annually	TAB Contractor, Commissioning Provider, or Design Professional
3	Check for proper separation of outdoor air intakes and exhaust air outlets to prevent/limit re-entrainment of potentially contaminated exhaust air.	Record instances where inlet and outlet do not meet code requirements. Contact design professional if issue arises.	High	Annually	No
4	Check that local temperature sensors and transmitters are clean and properly calibrated.	Utilize a calibrated, independent device to confirm reading.	High	Annually	No
5	Inspect control valves for proper operation and reporting to front end. Check for bypass and proper temperature control.	Physically feel if coil is bypassing heat and cooling unexpectedly. Inspect valve position and BMS to confirm expected result is occurring.	High	Annually	No
6	Measure system pressure levels for major pressure drop points throughout AHU (or RTU).	Provide pressure gradient of major changes in system pressure. Major locations for pressure drop readings include: heating and cooling coils, filters, and supply/return fan. Provide tracking of expected pressure gradient and airflows (cfm), review on annual basis, and correct any areas of high pressure drop.	High	Annually	May require outside consultant of some type (TABB, Commissioning agent).
7	Check VFDs to ensure they are operating in auto mode, and working correctly.	Inspect drives, compare readings to expected readings from front end, and consult with BMS contractor if required.	High	Semiannually	Not typically. May require assistance from BMS contractor as problems arise.
8	Review airflow and system capacities to determine if additional ventilation can be provided without adversely impacting equipment performance and indoor comfort. Ensure coil cleanliness to aid in performance and comfort.	Record heating and cooling capacities. Incorporate higher airflows for pandemic operating conditions.	High		TAB Contractor, Commissioning Provider, or Design Professional
9	Inspect areas of moisture accumulation for biological growth and proper drainage, such as drain pans	If issue is present, clean system.	Low	Annually	No
10	Inspect grilles, registers, and diffusers for damage, cleanliness, and impediments such as covered diffusers, blocked return grilles, overly closed supply diffusers/registers and return/exhaust grilles creating short cycling	Clean as needed to remove dirt build up.	Low	Semiannually	No
11	Check integrity of all panels on equipment. For rooftop units check integrity of curb.	Replace fasteners as needed to ensure proper integrity and fit/finish of equipment.	Low	Annually	No
12	Perform point to point check for pressure drop across AHU (or RTU).	Record temperature and static pressure in each compartment. Measure total airflow. Compare measured values with BMS to identify any sensors that need to be fixed.	Low		No

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

*ASHRAE prescribes a very detailed methodology approach as part of their *Building Readiness guidance document*[35] with regards to filter evaluation.

The summary of this guidance is:

- Before anything, gather initial documents and planning tools.
- Try to find existing TAB report if possible, or previous readings.
- Establish required airflow, based on review of technical documents.
- Consider use of outside TAB contractor or Commissioning agent for all readings.
- Document readings before any changes to establish existing airflow, pressure drop, etc.
- Install highest rated MERV filter which will still meet required airflow criteria, based on acceptable "dirty filter" pressure drop.
- Upon completion inspect the filter frames, ensure maintenance practices (listed on previous page).

Note that it is highly probable that a certified TAB contractor will be required for the above task.

[35]ASHRAE Building Readiness, October 2020, Filter Summary pages 16-20

AIR HANDLING UNITS & ROOFTOP UNITS CONT.

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
	Filters				
1	Check filter fit and housing seal integrity. Conduct integrity test to reset the baseline for clean filter installation during pandemic.	Clean and verify proper fit/finish.	High	Quarterly	No
2	Check for particulate accumulation on filters.	Clean or replace as needed to ensure proper operation.	High	Quarterly	No
3	Record filter specifications (MERV rating, manufacture, size, thickness, etc).	Update filter inventory on annual basis to avoid surprises when issue arises.	Low	Annually	No
4	Inspect and assess potential of filter racks to accept upgraded filters (size of filters and space considerations).	Review capability of filtration systems on annual basis to anticipate needs to increase filter effectiveness for future.	Low	Annually	
	UVGI and/or Air Cleaning Device				
1	Check UVGI lamps and/or air cleaning devices for cleanliness and proper operation, if applicable.	Recommend getting custom performance criteria from vendor and/or installation contractor	High	Annually	Yes, will most likely require independent testing company and/or Commissioning or TAB provider
2	Inspect AHU housing for potential to install UV lamps (ex. Upstream or downstream of coils, fan housing)	N/A	High	N/A	HVAC Engineer
	Airflow Stations				
1	Check to ensure air station is reading correctly	Verify airflow reading with either BMS or 3rd party testing	High	Annually	Yes, mostly BMS contractor and TAB contractor. Controls contractor may be required as well.
2	Check that measuring device is clean	Visually inspect and wipe device clean	High	Annually	No

06
HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

Fans (exhaust, supply, return, and traverse)

Proper operation of fans are critical to good IAQ. Ensure this checklist accompanies every AHU and RTU checklist (and HRU), and for any singular fan system. Ensure special consideration of exhaust fans, especially bathrooms and other high risk areas.

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Confirm measured airflow (cfm) and static pressure versus desired airflow and static pressure.	Provide airflow measurement and static pressure readings and confirm to either systems manual, Continuous Cx document or submittal. Adjust if needed.	High	Semiannually	Most likely require outside support such as TAB or Commissioning Contractor.
2	Check fan-belt tension, check for belt wear, and check sheaves for evidence of improper alignment or evidence of wear.	Correct tension and sheave alignment.	High	Semiannually	Most likely in house, but may require 3rd party support.
2	Check variable-frequency drive for proper operation.	Correct as needed. Ensure drive is working in auto mode. Troubleshoot if necessary.	High	Semiannually	Not typically. May require assistance from BMS contractor as problems arise.
3	Check control system and devices for evidence of improper operation.	Clean, lubricate, adjust.	High	Semiannually	Controls Contractor and Commissioning Contractor.
4	Check fan drive for problems due to poor alignment or poor bearing seating	Adjust and lubricate as necessary.	High	Annually	No
5	Check fan blades and fan housing.	Clean as needed.	Low	Semiannually	No
6	Inspect flexible connections on fan for noticeable rips or tears.	Repair as needed.	Low	Annually	No

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

CONTROL SYSTEMS

Ongoing commissioning is recommended for BMS systems using the checklist below, plus known issues you may be experiencing at your campus.

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Verify actuator movement and device response to control output.	Lubricate and align as needed.	High	Annually	Controls Contractor or Cx Contractor
2	Check control systems and devices for evidence of improper operation.	Clean, lubricate, adjust.	High	Semiannually	Controls Contractor or Cx Contractor
3	Review alarms and alarm histories. Simulate an alarm conditions which normally notify personnel via email or text message, to confirm proper operation.	Note and respond as required.	High	Quarterly	Controls Contractor or Cx Contractor
4	Verify no equipment has been left in override (hand/OFF instead of auto) either locally or through the BMS	Make corrections as required.	High	Monthly	No
5	Review sequences of control, trended points, time-of-day schedule and setpoints for each space to confirm consistency with facility operation.	Note and respond as required.	High	Semiannually	Controls Contractor, Cx Provider, Design Professional and/or TAB Contractor
6	Provide point to point checkout to confirm sensors, dampers, valves, etc are responding to commands and sensors are reading correctly.	Based off unit submittal construct a checklist for ongoing Commissioning, with columns for expected value, measured value, and notation for testing parameters.	High	Annually	May require 3rd party support. Special emphasis for key IAQ variables such as OA airflow and total airflow.
7	Identify if there is a demand control ventilation system in place.	Disable demand control ventilation during pandemic operating conditions.	High		Controls Contractor
8	For systems designed specifically for humidity control, measure relative humidity.	Adjust settings if outside of desired range (typically 40-60% RH). Check to see if the 40%-60% RH range can be maintained and adjust setpoints	Low	Quarterly	Design Professional
	Pneumatic Systems				
1	Check pneumatic lines for blockages.	Clean as needed.	Low	Annually	No
2	Check compressed-air system (e.g., compressor, dryer, receiver, blowdown valve) for proper operation. Check for evidence of oil carryover and condition of oil filter.	Clean and lubricate as needed.	Low	Monthly	Yes
3	Check for proper air pressure.	Clean, lubricate, adjust.	Low	Monthly	No

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

ENERGY RECOVERY VENTILATORS (AIR TO AIR HEAT RECOVERY DEVICES)

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Ensure airflows are within design value tolerance. Perform point to point checkout-similar to AHU checklist.	Confirm Airflow and pressure gradient to ensure units are providing required amount of air.	High	Annually	May require TAB or Cx Agent.
2	Check temperatures during operation to verify capacity is being maintained and no performance issues are present	Review and inspect temperatures of the systems, adjust as necessary	High	Annually	No
3	Calibrate controls and check for proper operation	Clean heat exchanger surface, and adjust to ensure proper operation.	High	Annually	Most likely BMS Contractor
4	Confirm static pressure (SP) on supply side is a minimum of 0.5" w.g. greater than the return. Refer to ASHRAE Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems.	Adjust airflows to maintain desired SP.	High	Annually	No, unless issues arises. May require support from TAB Contractor certified to check pressure.
5	Inspect filters and replace dirty of loaded filters. Inspect and repair seals between filters and at frame.	Inspect, repair, replace as necessary.	High	Quarterly	No
6	Verify outdoor air path is unobstructed.	Inspect, repair, replace as necessary.	Low	Quarterly	No
	Heat Wheels – System OFF				
1	Inspect wheel for damage and clean per manufacturer's requirements.	Clean wheel per manufactures instructions. Confirm suitability of any cleaning/disinfection solutions with mfg.	High	Semiannually	No
2	Check seals for proper seating. Ensure proper wheel direction	Inspect, repair, replace as necessary.	High	Semiannually	No
3	Confirm purge angle (if equipped) per system requirements	Inspect, repair, replace as necessary.	High	Semiannually	No
	Heat Wheels – System ON				
1	Confirm direction and speed of wheel rotation	Inspect, repair, replace as necessary.	High	Semiannually	No
	Plate Heat Exchangers – System OFF				
1	Inspect plates for damage and clean per manufacturer's requirements.	Clean wheel per manufactures instructions. Confirm suitability of any cleaning/disinfection solutions with mfg.	High	Semiannually	No
2	Inspect for gross leak paths between compartments	Patch leaks as required. Report major issues to management.	High	Semiannually	No
	Heat Pipes/Runaround loops – System OFF				
1	Inspect heat exchangers/components for damage and clean per manufacturer's requirements.	Clean wheel per manufactures instructions. Confirm suitability of any cleaning/disinfection solutions with mfg. Check coils for cleanliness.	High	Semiannually	No
	Heat Pipes/Runaround loops – System ON				
1	Check that airflows and fluid flow rates are maintained at design levels	Check coils for cleanliness.	High	Semiannually	No
2	Check system pressure (liquid side) to verify status	Check pressure readings during operation to verify proper operation	High	Annually	No

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

FAN COIL UNITS, PACKAGED TERMINAL AIR CONDITIONERS/HEAT PUMPS (PTACS/PTHPS), TERMINAL CONTROL DEVICES (VAVS, FAN-POWERED, BYPASS)

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Check fan blades and fan housing.	Clean as needed.	High	Annually	No
2	Check integrity of all panels on equipment.	Replace fasteners as needed to ensure proper integrity and fit/finish of equipment.	High	Annually	No
3	Check control system and devices for evidence of improper operation.	Clean, lubricate, adjust.	High	Semiannually	Controls Contractor
4	Check drain pan, drain line, coil, and other areas of moisture accumulation for visible signs of biological growth.	Clean, and verify proper operation.	Low	Annually	No
5	Check condensate slinger and/or drain system	Clean, and verify proper operation	Low	Quarterly	No
6	Ensure highest MERV rated filter is installed.	Verify MERV rating and compare to the desired, achievable rating according to capacity of unit	High	Quarterly	No
7	Check filters for proper alignment and fit.	Clean, and verify proper fit/finish (i.e. tight seal, no bend/breaks, etc	High	Quarterly	No
8	Check refrigerant system temperatures	When outside of recommended setpoints, identify and adjust to optimal levels	High	Annually	May require HVAC Engineer
9	If applicable: Check UV lamp for condensate drain pan for proper operation	Clean and verify proper operation of UV lamp intended to clean the drain pan	Low	Annually	No

COILS

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Verify coil velocities and unit discharge air temperature required to maintain desired indoor condition and avoid moisture carry over from cooling coils.	Measure and record airflow velocity and ensure velocity is within design criteria (typically 500 fpm or so).	High	Annually	TAB Contractor, CX Contractor, or Design Professional
2	Check coil for general cleanliness and obstructions. Take differential pressure reading at multiple spots and shine flashlight to check for blockage. Assess areas with condensate to confirm airflow	Visual Inspection, clear obstructions if required	Low	Annually	No
3	Check drain pan, drain line, coil, and other areas of moisture accumulation for visible signs of biological growth.	Clean, and verify proper operation.	Low	Semiannually	No
4	Check drain pans for cleanliness and proper slope.	Clean, and verify proper operation.	Low	Semiannually	No
5	Check P-trap	Prime as needed to ensure proper operation.	Low	Quarterly	No

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HVAC SYSTEMS EVALUATION CHECKLIST

CHECKLISTS CONT.

DEHUMIDIFICATION & HUMIDIFICATION DEVICES

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Check for fouling, corrosion, or degradation of manifolds, piping, and steam generator	Clean and restore as needed to ensure acceptable condition.	High	Semiannually	No
2	Check for proper fluid flow and for fluid leaks.	Adjust flow when outside of recommended flow range. When leaking, find and record the location of identified leaks.	High	Annually	No
3	For systems designed specifically for humidity control, measure relative humidity.	Clean, lubricate, and verify proper operation.	Low	Quarterly	No
4	Inspect distributors, drain pans, and other areas of moisture accumulation for biological growth.	Clean, and verify proper operation.	Low	Annually	No
5	Check strainers	Correct as needed. Clean housing, and tighten connections as needed. Clean strainers.	Low	Annually	No

DUCTWORK & DISTRIBUTION

	Inspection Task	Maintenance Task	Priority	Frequency	Requires External Staff?
1	Inspect ductwork for leaks	Visually inspect ductwork. Investigate areas which have airflow issues for duct leakage.	High	Annual	No
2	Inspect for duct obstructions such as crushed duct, flexible duct is taught and free of kinks or folds, disconnected branches, improperly closed dampers	Visually inspect ductwork. Investigate areas which have airflow issues for high pressure drop issues.	High	Annual	No
3	Inspect air distribution system for proper air mixing within the space that does not cause strong air current or direct airflow to pass from person-to-person	Adjust distribution system as necessary	High	N/A	No
4	Inspect duct interior for cleanliness	Visual inspection, check diffusers to identify likely trouble areas	Low	Annual	No
5	Inspect grilles, registers, and diffusers for cleanliness	Visual inspection	Low	Annual	No

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