# Design Guidance for Education Facilities:
## Prioritization for Advanced Indoor Air Quality
### Version 2.0

**Developed by**
ASHRAE Technical Committee 9.7, Educational Facilities

Peachtree Corners

This document was developed by
ASHRAE Technical Committee (TC) 9.7, Educational Facilities.
ASHRAE TC 9.7 is concerned with the application of heating, ventilating, air-conditioning, refrigeration, life safety, and energy conservation systems to educational facilities.

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# Contents

# Intent and Scope

This guidance document is a tool for the design professional and mechanical contractor. It is intended to help guide the discussion with school personnel on options available to improve indoor air quality (IAQ) based on regional needs and available funding as well as to provide guidance to owners, operators, designers, and professional service providers on how to best implement IAQ improvements, including risk mitigation strategies, in educational facilities. It will also help facilitate discussion between designers and stakeholders, identify minimum recommendations, and discuss further considerations to improve IAQ and reduce the transmission risk of infectious pathogens and other contaminants of concern. This guide is consistent with other ASHRAE publications and will be updated to align with other standards as they are adopted or updated.

This guidance is intended to assist in the retrofit of existing facilities or as a baseline for new facilities. It is not intended to replace or supersede other documents, including, but not limited to, other standards such as ASHRAE Standard 62.1 or the proposed ASHRAE Standard 241. Instead, this guidance is intended to illustrate principles and practical considerations within the existing framework to mitigate risk. HVAC professionals should use this guidance in conjunction with all relevant bylaws, codes, and standards.

# Purpose

This document should be used to prioritize decisions related to heating, ventilating, and air-conditioning (HVAC) system design and operation for existing facilities (commissioning, maintenance, improvement, and retrofit projects) and new facilities to improve indoor air quality while limiting energy consumption.

IAQ upgrades can improve learning outcomes and mitigate the risk of transmission of airborne pathogens within the educational environment.

This guide is intended to help qualified professionals, including HVAC engineers; commissioning agents; testing, adjusting, and balancing (TAB) providers; and facility managers assess existing facilities and identify appropriate design decisions for new facilities. Every school, and its HVAC systems, is unique and requires its own distinct solutions. This document provides prioritization themes but does not replace the efforts of a qualified professional in assessing each facility's unique characteristics.

This document is broken into several sections including Prerequisite Tasks, Very High Priority Tasks, High Priority Tasks, and Medium Priority Tasks. Within each of these sections are steps or HVAC system strategies for consideration, typically with base minimum and advanced IAQ strategies, targets, or requirements.

The “base minimum” recommendations, beyond code requirements, should be implemented to meet a minimum level of air quality and risk mitigation. These strategies were developed through collaboration and review by members of ASHRAE Technical Committee 9.7, Educational Facilities, and members of the Epidemic Task Force (ETF) Schools Team. The recommended strategies have been implemented across many educational facility systems worldwide.

The “advanced IAQ” recommendations are generally believed to represent best practices that may not be appropriate for all applications but are worth consideration for adoption to improve beyond the base minimum recommendations. Various combinations of these strategies have been implemented in facilities to address concerns related to airborne pathogens and indoor air quality in general.

# Prioritization for Advanced IAQ: Checklists

| Complete | Prerequisite Tasks |
|---|---|
| | Ventilation verification of HVAC airside components |

| Base | Improved | Advanced | Very High Priority Tasks |
|---|---|---|---|
| | | | HVAC equipment filtration upgrade |
| | | | HVAC for wellness/nurse suites for pre-K–12 |
| | | | Classroom and assembly space air distribution effectiveness |

| Base | Advanced | High Priority Tasks |
|---|---|---|
| | | IAQ sensors with data aggregation platform |
| | | New HVAC equipment to achieve ASHRAE-recommended air change rates (ACH) |
| | | Classroom-level air cleaning |
| | | Restroom exhaust and air filtration upgrades |
| | | Staff training and documentation organizational platform |
| | | UV-C/UVGI for air handlers |

| Base | Advanced | Medium Priority Tasks |
|---|---|---|
| | | Humidification and dehumidification systems |
| | | Energy efficiency offset control schemes for advanced IAQ |
| | | Operable windows |

# Prioritization for Advanced IAQ: Budgetary Guidelines

| Low | High | Units | Prerequisite Tasks |
|---|---|---|---|
| $0.35 | $0.75 | ft$^2$ | Ventilation verification assessment |
| $15,000 | $25,000 | Building | Budgeting and planning |

| Low | High | Units | Very High Priority Tasks |
|---|---|---|---|
| $0.30 | $1.50 | cfm | HVAC equipment filtration upgrade |
| $350 | $500 | ft$^2$ | HVAC for wellness/nurse suites for pre-K–12 |
| $0.20 | $0.35 | ft$^2$ | Classroom and assembly space air distribution effectiveness |

| Low | High | Units | High Priority Tasks |
|---|---|---|---|
| $0.50 | $1.00 | ft$^2$ | IAQ sensors with data aggregation platform |
| $5.00 | $10.00 | ft$^2$ | New HVAC equipment to achieve ASHRAE-recommended ACH |
| $1000 | $2000 | Classroom | Classroom-level air cleaning |
| $1500 | $3000 | Restroom | Restroom exhaust and air filtration upgrades |
| $1500 | $2000 | Cost/person/ week | Staff training and documentation organizational platform |
| $0.35 | $0.70 | cfm | UV-C/UVGI for air handlers |

| Low | High | Units | Medium Priority Tasks |
|---|---|---|---|
| $1.50 | $4.00 | cfm | Humidification and dehumidification systems |
| $15,000 | $35,000 | Site | Energy efficiency offset control schemes for advanced IAQ |
| $1500 | $3,500 | Window | Operable windows |

Note: The budgetary numbers are to be used for capital planning and does not substitute for an actual design and construction bid process. The general ranges can be adjusted based on local and climatic conditions. Users should budget 5% yearly escalation in the cost ranges after 2023. Budgets will vary based on the age and condition of the school and HVAC systems. Budget costs assume minimal architectural work. Structural, phasing, temporary equipment, electrical or plumbing upgrades, extensive demolition of existing system, and replacement of specialty finishes are not included in the ranges.

# Prerequisites

Establishing an IAQ building-level improvement plan is a process that involves several components. These prerequisites are about establishing objectives and existing conditions (where applicable). Without these initial steps, it is not possible to develop a comprehensive strategy to mitigate risk and maintain a high level of IAQ. It is important to understand that these strategies reduce, but do not eliminate, the potential for airborne transmission and must be used as part of a comprehensive layered risk management approach. It should also be noted that while the current focus may be on SARS-CoV-2/COVID-19, improving indoor air quality in education facilities will have similar benefits for other airborne pathogens, and studies have shown reduced absenteeism and better performance from students in facilities with better indoor environments.

The first step is to determine the appropriate level of risk tolerance/mitigation and associated general system operating characteristics. Once this step has been completed, the required scope of work for existing facilities or new facilities should be developed. Factors include, but are not limited to, identifying and prioritizing buildings needing improvements, which systems are currently in place, and whether those systems function as intended. Much of the initial data collection can be completed by reviewing existing records and documentation where available. The data may come from record drawings, manuals, control systems, personnel interviews, or maintenance records. The initial data collection process may be shared between facility stakeholders including administrative, maintenance and operations, and HVAC professionals as needed to collect the summary of the systems to be analyzed.

From this initial facility and equipment list, a scope of work can be generated to verify the system performance. An HVAC professional should be engaged to help develop the plan for assessment of the existing equipment and establish a ventilation verification and testing and balancing of HVAC airside components plan. A combination of the records and verification reports will create an accurate picture of the existing systems and their condition.

Next, an initial assessment of HVAC risk can be determined using site-specific risk analysis tools such as the Wells-Riley Equations, Equivalent Outdoor Air Rate Calculator, and/or other assessment tools. The resulting analysis should give an estimate of the risk in specific spaces and may help develop an equitable strategy between facilities and spaces with varying configurations. There are several mitigation strategies that effect other components of risk, such as common areas, but the establishment of a summary of the existing conditions and discussion of risk acceptance are critical in the development of a comprehensive plan, which is why they are considered prerequisites to the process. While variations of these prerequisites will exist in different facilities and areas, the inclusion of this process and the discussion of it between stakeholders and HVAC professionals is foundational in the process.

# Ventilation Verification of HVAC Airside Components (Existing Facilities Only)

## Overview

Perform a physical assessment of existing HVAC infrastructure and provide a written condition assessment. Verify operation and conditions of existing systems. This baseline assessment must be performed by a skilled, trained, and certified technician. Upon completion, the assessment should be submitted to an HVAC design professional for determination of adjustments, replacements, repairs, and upgrades. Where possible, this can be compared to record drawings, manuals, and noted deficiencies in performance.

### Involved Parties

A skilled, trained, and certified technician performs the physical assessment in coordination with facilities personnel and a qualified design professional, as defined by state or provincial guidelines.

### Procedure

Refer to Additional Guidance for sample ventilation verification assessment test sheets and method of procedures (MOP). Sample procedures should be altered to meet local requirements, updated recommendations, and site-specific equipment.

## Base Minimum

### For All Airside Systems

- Document filter Minimum Efficiency Reporting Value (MERV) values and ensure proper installation with minimum bypass air.
- Physically verify and document ventilation rates. Adjust the ventilation rates to accommodate the building elevation and corresponding air density per ASHRAE Standard 62.1, *Ventilation and Acceptable Indoor Air Quality* (6.2.1.1.3).
- Physically verify demand control ventilation (DCV) operates as intended. A minimum of 10% sampling is acceptable for verification. If carbon dioxide is used as a surrogate for occupancy, confirm sensors are installed at space level (not in common return) and confirm calibration of sensors (minimum of five per facility or 10%).
- Document initial and periodic calibration procedure and implement with calibration period not to exceed five years.
- Air distribution: Measure a minimum of 10% of all zones/inlets/outlets for a cfm sampling. These should be representative of the overall HVAC system. Zones measured should be representative of zones in system (closest and furthest from equipment, interior and exterior spaces, etc.).
- Document building differential pressures of rooms temporarily occupied by sick students and staff (i.e., nurses' isolation rooms). Pressure should be read between space of concern and adjacent occupied area(s).

**Figure 1** Testing and balancing of HVAC airside components.
*Source: www.nemionline.org/testing-adjusting-and-balancing-hvac-systems-an-overview-of-certification-agencies/*

- Document existing sequence of operations (SOP/SOO) and operational controls.
- Document ambient outdoor $CO_2$ conditions and differential to indoor spaces. Trend the $CO_2$ levels over the duration of peak occupancy. If $CO_2$ levels exceed recommended limits (typically outside air level +750 ppm set point or 1100–2000 ppm) for 90 minutes, further recording should be implemented. Recommended limits are based on ASHRAE TC 9.7 member author's design experience.
- Perform testing of PM2.5, PM10, and VOC levels in a minimum of 10% of the spaces hourly during occupied times over a minimum period of one week.
- Verify that equipment is operating as outlined in the SOP/SOO.
- Report and remediate any issues and coordinate with the qualified design professional.

## Exhaust

- Air distribution: Survey a minimum of 10% of all exhaust inlets, with measurements taken in areas that will represent operation throughout the system. Ensure that systems are all operating in occupied mode.

### Limited or No Existing Mechanical Ventilation

In cases where there is limited or no existing mechanical ventilation, the assessment should focus on available strategies to provide ventilation including, but not limited to, operable windows and building chases. Provide the qualified design professional with documentation for future ventilation improvements for concurrence.

## Advanced IAQ

### For All Airside Systems

- Determine air handler capability to accommodate MERV 13 filter.
- Verify physical ability to increase ventilation above scheduled value.
- Verify physical ability to override and/or disable the DCV.
- Measure 100% of all air distribution inlets/outlets.
- Document building pressure relationships of all rooms as recommended by your HVAC professional.
- Test a minimum of 10% of sensors for accuracy and document the drift of the sensors in comparison to handheld sensor readings. Calibrate sensors.
- Verify operational controls respond correctly.
- Schedule a periodic physical ventilation verification assessment of primary HVAC systems every five years.
- Establish a verification and calibration program to confirm operation of sensors.

### Exhaust

- Survey 100% of all air distribution exhaust inlets for a sampling.

## Additional Guidance

ASHRAE TC 7.7, Testing and Balancing.

Meyers, F., and T. Pistochini. 2020. Testing, adjusting and balancing HVAC systems: An overview of TAB certification agencies. WCEC technical report. Davis, CA: University of California Davis Western Cooling Efficiency Center. https://wcec.ucdavis.edu/wp-content/uploads/TAB-Technical-Report-051220.pdf.

- Associated Air Balance Council (AABC).
- National Environmental Balancing Bureau (NEBB).
- Testing, Adjusting and Balancing Bureau (TABB).

IEQ Guidelines. 2022. Copy of all IAQ guidelines reports. https://ieqguidelines.org/table.html.

NEMI. 2022. Sample ventilation verification assessment test sheets. https://www.nemionline.org/vvr-for-contractors/.

NEMI. 2022. Ventilation verification specification. https://www.nemionline.org/ventilation-verification-specification/.

Ruch, C., and T. Pistochini. 2021. White paper: Proposed ventilation and energy efficiency verification/repair program for school reopening. NEMI/University of California Davis Energy and Efficiency Institute. https://ucdavis.app.box.com/v/ProposedVentilationProgram.

UC Davis Energy. 2020. Importance of ventilation in schools. YouTube video, produced by University of California Davis Western Cooling Efficiency Center. https://www.youtube.com/watch?v=F9hB9BgonHs.

# Budgeting and Planning

## Overview

HVAC system baseline assessment—ventilation verification of HVAC airside components—should be conducted prior to this budgeting exercise if "need-based" is the primary factor in determining funding allocations. When prioritizing IAQ projects and budgeting, stakeholders should evaluate a matrix of need to provide a basis for the funding allocation and project scopes.

The main approaches and factors to consider when creating an equitable plan for improving IAQ across a portfolio of schools are as follows:

- Facility-based approach—disburse funding equally by school
- Need-based approach—disburse funding based on the greatest need as determined during the ventilation verification assessment of HVAC air-side components
- Student-based approach—disburse funding based on a per capita ratio
- Risk-mitigation approach—disburse funding to create HVAC-centric projects that reduce the probability of transmission both in the classroom and schoolwide

### Involved Parties

Design engineers, facility managers, architects, building operations staff, facility assessment professionals, and local health officials.

## Facility-Based Approach

For school systems or multi-facility funding allocation challenges, the facility-based approach simply divides the available funding by the number of facilities, thereby providing an equal amount of funding per building/site. Once the funding allocation has been determined for the school or school system, the projects determined by the prerequisite ventilation verification assessment will be addressed.

## Need-Based Approach

The need-based approach is derived from the prerequisite ventilation verification assessment of HVAC airside components, which allows for the school's HVAC systems to be ranked in order of greatest need of IAQ intervention. The physical assessment determines the existing HVAC infrastructure's ability to meet design intent and minimum regional requirements. The goal of this approach is to bring all school buildings to a common standard of IAQ, which will most likely entail varying funding allocations per school. Based on the equipment condition and determined IAQ goal, some schools may require a majority of the available funding while other schools may receive minimal funding due to unbalanced needs discovered in the ventilation verification assessment.

## Student-Based Approach

The student-based approach allocates funding based on each school's student population. The stakeholders divide the total funding available by the school system enrollment to create a per capita allocation amount. The per capita amount is then applied to each school's enrollment. Once the funding allocation has been determined for the school, the projects determined by the prerequisite ventilation verification assessment will be addressed. It is recommend that a sample matrix be created. An example is provided below:

| Approach | Weighted Factor | Score | Total Score |
|---|---|---|---|
| Facility-based | | | |
| Student-based | | | |
| Need-based | | | |
| Risk-mitigation | | | |

## Reduction of the Probability of Transmission

An IAQ risk assessment should be performed as part of the basis of design for any IAQ upgrade project.

Designers and engineers should evaluate their design approaches for effectiveness in reducing the risk of transmission, and educational facilities should have an understanding of the expected results. A number of calculation tools can be used to compare HVAC options to balance effectiveness and budgetary constraints. It is recommended that stakeholders determine the acceptable level of risk as defined by their governing bodies. For example, based on a risk assessment of a school, it may be determined that the deployment of air cleaners in each classroom provides the fastest, most economical method of increasing the clean air exchange rate, thereby reducing the probability of infection from airborne pathogens.

The following list provides some examples of available risk analysis tools. The site-specific strategy employed should be developed in collaboration with stakeholders and the HVAC professional. Note that inclusion of these calculators is to provide examples of risk assessment tools and is not an endorsement of the tool itself.

- 2020 COVID-19 Aerosol Transmission Estimator
- Harvard–CU Boulder Portable Air Cleaner Calculator for Schools, v1.3
- SETTY-5.2, Small Space Airborne Transmission Infection Rate Estimator

Once the acceptable level of risk has been determined for the school, the projects determined by the prerequisite ventilation verification assessment will be addressed.

# Very High Priority Tasks

## HVAC Equipment Filtration Upgrades

### Overview

By improving the filtration in the air handlers, it is possible to decrease the chance of aerosolized viral particles being spread through the air distribution system.

While higher filtration is more effective, it may not be practical, because there are diminishing returns in improvement of particulate removal and increases in static pressure and cost. Additionally, existing equipment may have several limitations such as fan static capacity. Higher levels of filtration are better; however, research has determined that diminishing returns in the effectiveness of particle removal begin at MERV 13 to MERV 14 filter ratings.

An increase from MERV 8 or MERV 11 represents a substantial increase in the efficacy of filtration of small infectious particles. Filter frame size should be evaluated by your HVAC professional to handle the filter upgrade. If the filter frame cannot be increased, proceed with the highest level MERV filter that will

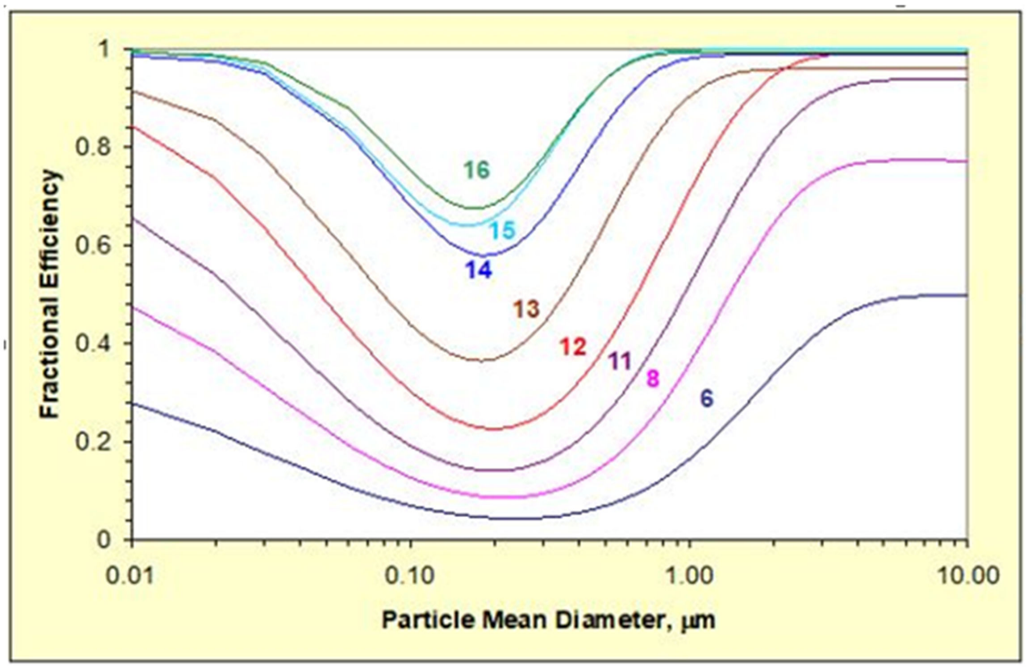


**Figure 2** MERV filter models.

*Source: Kowalski, W.J., and W.P. Bahnfleth. 2002. MERV filter models for aerobiological applications. Air Media, Summer.*

not require the equipment or ductwork to be changed. The introduction of new filters may create higher O&M and energy costs plus a higher pressure drop, the impacts of which should be reviewed by your HVAC professional.

### Involved Parties

Design engineers, facility managers, architects, TAB contractor/technician, and building operations staff.

## Base Minimum

- Assess existing filtration levels and create an inventory of existing filtration efficiency (per ASHRAE Standard 52.2) and ventilation volumes.
- Assess ventilation system capacity for higher levels of filtration, including motor and physical dimensions of air handlers.
- Apply the highest MERV filter for the HVAC units (local, central, and DOAS) given limitations with increased pressure drop. MERV 13 is the recommended minimum.
- Create and follow safe procedures for filter maintenance and operations per the Occupational Safety and Health Administration (OSHA) and ASHRAE Standard 180.
- Verify airflows after filtration level changes.
- Monitor loading pattern on filters after changes and adjust filter change schedules to meet new loading patterns.
- Label all filters with the manufacturer's name showing the MERV rating and date of filter change.

## Advanced IAQ

- Make duct modifications where required to ensure that a minimum level of MERV 13 is reached in all areas and MERV 14 where possible.
- Consider adding differential pressure sensors to monitor the status of filters.
- Consider alternate filter locations in return duct or grille, but consider static pressure drop implications and relationship with outside air dampers.
- Consider the addition of a prefilter to extend primary filter life.
- Consider UL-listed electrostatic devices.
- Consider adding HEPA filters in critical/ higher density areas with lower outside air volumes.
- Consider additional treatment technology to inactivate airborne infectious aerosols (refer to the ASHRAE Epidemic Task Force's document for reopening schools and universities for additional guidance).
- Consider having facility staff who perform filter change-out procedures to be trained for proper installation and maintenance of new filters and air cleaning systems.

## Additional Guidance

ASHRAE. 2017. ASHRAE Standard 52.2-2017, *Method of testing general ventilation air-cleaning devices for removal of efficiency by particle size*. Peachtree Corners, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/ashrae-52-2-2017?product_id=1942059.

ASHRAE. 2021. ASHRAE position document on filtration and air cleaning. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/about/position%20documents/filtration-and-air-cleaning-pd-feb.2.2021.pdf.

EPA. 2022. What is a MERV rating? https://www.epa.gov/indoor-air-quality-iaq/what-merv-rating.

UC Davis Energy. 2021. The importance of filtration in schools. YouTube video, produced by University of California Davis Western Cooling Efficiency Center. https://www.youtube.com/watch?v=ycgLBUfIM_c.

# HVAC for Wellness/Nurse Suites for Pre-K–12

## Overview

This section focuses on the educational facility's wellness/nurse suite where students with medical issues are placed during the period prior to them being transferred out of the facility. It is intended to be a transitory space to temporarily hold potentially infectious persons. Due to the operation of many facilities, this space is often located at or near the central office, which also acts in a security role by controlling access to the facility. The combination of keeping a potentially infectious person near a specifically designed point where all traffic is being routed presents an increased level of risk, and additional consideration of strategies to mitigate this risk may be warranted.

The facility size should be considered along with its location, risk tolerance, and facility operation. A larger facility may have a medical professional occupying the suite, while in smaller facilities, this task may be completed by persons with some first aid training and consist of a less complex approach.

This section refers to pre-K through grade 12 facilities. For post-secondary facilities, refer to ASHRAE Standard 170 or other standards, as appropriate. Due to the increased possibility of an infected person entering a nurse's suite, greater caution and a higher level of air quality must be designed and installed similar to an airborne isolation room in a hospital. While there are degrees of protection, air should not be recirculated from this space to other occupied building areas.

Isolation of a nurse's suite should consist of architectural barriers and controlled pressure relationships between areas to mitigate the risk of airborne transmission. The pressure of the space should be positive to outside but negative to adjacent spaces, as this approach should reduce risk to the occupants. It is important to consider the pressure relationships, air changes, space exhaust, and operational policies and procedures.

Furthermore, the design approach should accommodate the safety and protection of the attending nurse or staff. When locating a nurse's isolation suite, the safe and efficient movement of a sick person from the nurse's suite out of the building needs to be considered to minimize the release of pathogens in the building.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

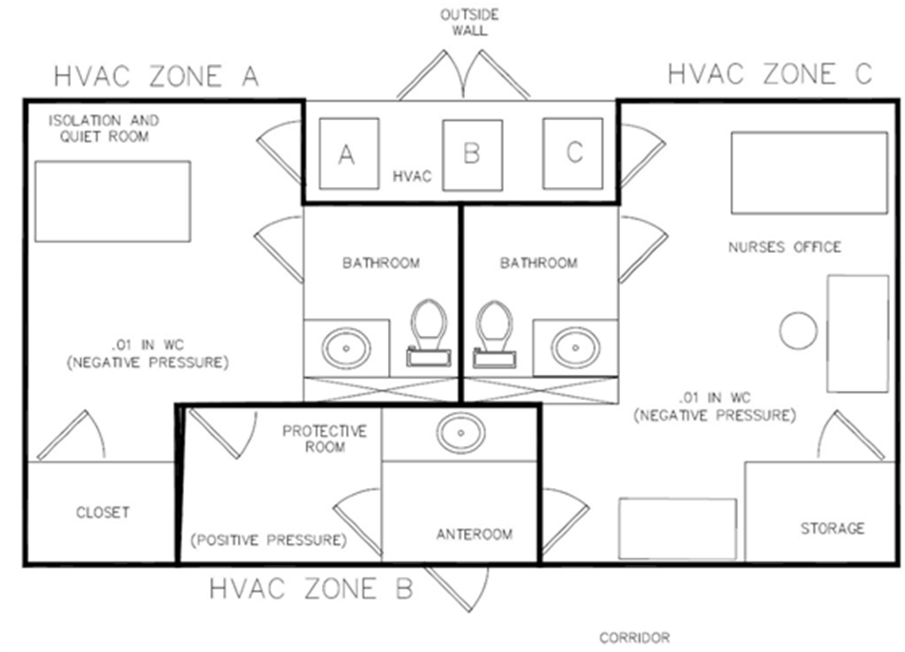


**Figure 3** Indicative wellness/nurse suite prototype configuration.
*Source: Raj Setty/ASHRAE Epidemic Task Force. 2021. Schools and universities. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf.*

## Base Minimum

- Wellness/nurse office or suite (any space intended for occupancy by individuals who are sick or suspected to be sick) should be maintained at a negative pressure with respect to corridors and adjacent spaces.
- Air may be recirculated within the space only but may not be returned and recirculated to other spaces. All air leaving the space should be exhausted to outdoors. Exhaust air may pass through energy recovery devices serving other building areas being exhausted, as long as systems comply with ASHRAE Standard 62.1. Exhaust air intakes should be fully ducted to intakes in space.
- Air recirculated within the space should be filtered through filter media with minimum MERV rating of 13.
- Maintain a minimum air change rate to space of six total air changes per hour (ACH) and minimum of two ACH of outdoor air. All air in the waiting areas and the isolation room should be exhausted when building or space is occupied.
- Special attention should be given to proper location of supply air diffusers and return/exhaust air grilles.

## Improved IAQ

- Create a school/building-specific nurse's isolation suite. The number of isolation rooms will depend on the school programming requirements.
- Do not mix supply air and return air from isolation room with any other spaces when in isolation mode.
- Maintain a minimum clean ACH of 6 in all conditioned spaces in the nurse's suite, 10 ACH in the waiting room, and 12 ACH in the isolation room(s). All air in the waiting areas and the isolation room should be exhausted when building or space is occupied.
- Exhaust directly to outdoors. Follow ASHRAE Standard 62.1 requirements to avoid re-entrainment of contaminated air. If there is a concern of recirculation, HEPA filtration on exhaust could be added.
- The nurse's suite should be under negative air pressure in relation to building corridors and adjacent spaces.
- Follow applicable ASHRAE Standard 170's most recent tables for general outpatient spaces (Table 8-2) and 2019 California Mechanical Code (Ventilation).
- Supply air should have a minimum of MERV 13 or higher filtration.
- Special attention should be given to proper location of supply air diffusers and return/exhaust air grilles (low return is recommended). In the isolation room, the exhaust grille should be located close to the patient in the proper elevation.
- Provisions for biohazard waste and personal sanitation including, but not limited to, hand wash, showers, water closets, etc.
- Provisions for PPE storage and application to mitigate the risk of PPE becoming contaminated.

## Advanced IAQ

- Create school/building-specific nurse's isolation suite(s) based on the unique school population.
- 100% OA dedicated outdoor air unit (DOAU) with air-to-air energy recovery (no cross contamination/carryover in the energy recovery heat exchanger). The unit should be capable of switching to recirculation/minimum OA when applicable with the ability to provide and control the desired thermal conditions (space temperature and humidity).
- Treat as Airborne Infectious Isolation (AII) per ASHRAE Standard 170 and *ASHRAE Handbook*, Chapter 9 (2019).
- ACH = 12 to 20.
- Add UVGI to dedicated HVAC unit or other approved disinfection technology. Upper air room (with fan as an option) UVGI can be also considered, specifically in critical areas such as isolation and waiting rooms.
- Dedicated bathrooms that should be kept under negative pressure in relation to adjacent spaces.
- Nurse's station infirmary beds should be defined based on the population of the school (typically 1 bed /200 students).
- Recommend locations of nurse's office HVAC on an exterior wall.
- Maintain pressure relationship for room, ante room, and corridor.
- Directional airflow designer to consider the airflow pattern.

- Establish an annual verification program to confirm airflows and pressure relationships by a certified technician.
- Follow maintenance and operations schedule established in ASHRAE Standard 62.1.
- Add a separate power supply for all equipment and ventilation to standby power system.
- Provide permanently mounted sensors for IAQ monitoring and occupancy. At minimum, parameters such as $CO_2$, total volatile organic compounds (TVOCs), PM2.5, and PM10 should be monitored.

## Additional Guidance


ASHRAE. 2017. ASHRAE Standard 170-2017, *Ventilation of healthcare facilities*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/standards-and-guidelines/standards-addenda/ansi-ashrae-ashe-standard-170-2017-ventilation-of-health-care-facilities.

ASHRAE. 2022. ASHRAE Standard 62.1-2022, *Ventilation and acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

ASHRAE Epidemic Task Force. 2021. Schools and universities. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf.

NIEHS. Handout 1: Infection control checklist for risk assessment and precautions for construction & renovation. https://tools.niehs.nih.gov/wetp/public/Course_download2.cfm?tranid=9806.


# Classroom and Assembly Space Air Distribution and Dilution Effectiveness

## Overview

While it is possible to identify the location of the potential infector in some applications, that is not applicable in a classroom. Any occupant may potentially be an infector. Given that the potential infector could be anywhere in the room, the best applied strategy should ensure there are no direct drafts that could concentrate infectious aerosols. Maintaining good mixing will also reduce thermal stress and conform to energy standards such as ASHRAE/IES Standard 90.1 for discharge air temperature requirements.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

## Base Minimum

- Ensure air grilles and diffusers are in good operating condition and are not configured such that they will create drafts.

- For modifications or new distribution systems, follow ASHRAE/IES Standard 90.1, which limits discharge temperature to 20°F (11°C) above room temperature.
- Design intent should minimize cross-flow between occupants but maximize room volume dilution.
- Minimum outside air should not be substituted with increased ventilation effectiveness strategies.
- Review temporary dividers impact on air distribution to avoid creation of drafts and concentrations of flow.

## Advanced IAQ

- Follow ASHRAE Standard 55 requirements to maintain a maximum of 5.4°F (3°C) of temperature difference between the head and foot level of the space and air velocity.
- The *ASHRAE Handbook—HVAC Applications* recommends mixing; however, care must be taken to minimize transfer air among occupants.
- Consider vertical separation in flow patterns including, but not limited to, supply air high and return air low, underfloor air distribution (UFAD), and displacement ventilation (DV). Different strategies should be analyzed for different operating conditions in climate zones where both heating and cooling operation will be required during occupied periods.
- Air cleaners may be considered to improve IAQ, but their impact on existing distribution effectiveness should be reviewed.
- CFD modeling can be used to consider different approaches and model various classroom configurations and desk arrangements.

## Additional Guidance

ASHRAE. 2019. ASHRAE/IES Standard 90.1-2019, *Energy standard for buildings except low-rise residential buildings*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standard-90-1.

ASHRAE. 2020. ASHRAE Standard 55-2020, *Thermal environmental conditions for human occupancy*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy.

# High Priority Tasks

## IAQ Sensors with Data Aggregation Platform

### Overview

IAQ sensors distributed throughout the building will provide a baseline IAQ profile of the entire building. The goal of this section is to inform practitioners on how to prepare sensors and interpret readings for an IAQ-centric HVAC system. The driving force for our industry is energy efficiency, which has been the predominant underlying engineering design dogma. This must now be balanced with a high level of indoor air quality for the health and welfare of the learners. The best way to balance IAQ and energy efficiency is to deploy a suite of IAQ sensors to provide a data-driven approach to proper HVAC operations.

The designer must, at a minimum, evaluate $PM_{2.5}$/$PM_{1.0}$/$PM_{0.5}$, $CO_2$, temperature, TVOCs, and humidity, which all paint a picture of the optimal air quality for the teaching space. Baseline should be created in spaces that reflect a minimum of six months of data collection through both occupied and unoccupied times. Sensors should be UL 2905 compliant.

#### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

### Base Minimum

- IAQ sensors deployed at all HVAC main central air handling stations during all periods of occupancy.
- IAQ sensors deployed at 10% of the classrooms to provide an IAQ profile of the distribution systems.
- Readings should be taken daily, and trending data shared with a BMS or web/cloud-based data repository and reporting platform. Design team to set thresholds for $CO_2$, TVOCs, and PM levels. Thresholds should incorporate time elements and be established on local outdoor air quality as the baseline.
- Monitor $PM_{2.5}$, $CO_2$, temperature, TVOCs, and humidity.
- Establish an ongoing testing and verification program as per Table 8.1 in ASHRAE Standard 62.1:

  *Inspection/Maintenance Task*

  *ad. Verify the accuracy of permanently mounted sensors whose primary function is outdoor air delivery monitoring, outdoor air delivery verification, or dynamic minimum outdoor air control, such as flow stations at an air handler and those used for demand control ventilation, including $CO_2$ sensors. A sensor failing to meet the accuracy specified in the O&M manual shall be recali-*

*brated or replaced. Performance verification shall include output comparison to a measurement reference standard consistent with those specified for similar devices in ASHRAE Standard 41.2 or ASHRAE Standard 111.*

## Advanced IAQ

- IAQ sensors deployed throughout the building at no less than one sensor per 3000 $ft^2$.
- Readings should be taken every five minutes and trending data shared with a BMS.
- Data aggregation and analysis software to be provided to create an IAQ daily profile.
- BMS should calculate the $PM_{2.5}$, $CO_2$, temperature, TVOCs, humidity levels of degradation from peak occupancy to baseline normal levels. HVAC should be capable of adjustments to increase clear air delivery rate (CADR) levels to bring the classroom IAQ to baseline levels within 60 minutes of peak. Baseline algorithms should take IAQ alarms and adjust HVAC sequences for flushing, higher ventilation, or airflow changes to improve the IAQ in real time. Possibly incorporate totalizers for number of hours room is outside of specified parameters so that either scheduling or equipment can be modified to improve IAQ.
- Consider monitoring $PM_{10}$, $PM_{1.0}$, and different types of volatile organic compounds.
- Physically verify sensor accuracy annually.
- Consider revising control strategy to maximize IAQ. If there is good outside quality air of a suitable temperature and humidity, maximize outdoor air.

## Additional Guidance


AIRNOW. 2022. Air quality index (AQI) basics. https://www.airnow.gov/aqi/aqi-basics/.

ASHRAE. 2022. ASHRAE Standard 62.1-2022, *Ventilation and acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

CDC. 2019. NIOSH pocket guide to chemical hazards. https://www.cdc.gov/niosh/npg/npgd0103.html.

EPA. 2022. Creating healthy indoor air quality in schools. https://www.epa.gov/iaq-schools.

IEQ Guidelines. 2022. Copy of all IAQ guidelines reports. https://ieqguidelines.org/table.html.

UC Davis Energy. 2020. Importance of ventilation in schools. YouTube video, produced by University of California Davis Western Cooling Efficiency Center. https://www.youtube.com/watch?v=F9hB9BgonHs.

# New HVAC Equipment to Achieve ASHRAE-Recommended Air Change Rates

## Overview

New HVAC systems should be designed to comply with the most current adopted mechanical and building codes within the jurisdiction where the facility is located, including the code-required minimum ventilation standard. In the absence of a code official or authority having jurisdiction over the design and construction of a new HVAC system, or an adopted code, ASHRAE recommends designing the systems to provide the minimum ventilation rates in the breathing zone or ventilation effectiveness breathing zone as determined using Table 6-1 in ASHRAE Standard 62.1, *Ventilation and Acceptable Indoor Air Quality*.

Your HVAC professional should review system capacity, review air delivery rates to determine the highest MERV filtration for reducing contagions, replace or upgrade filters where needed, and verify that replaced or upgraded filters are installed correctly. Furthermore, clean air delivery rates should be calculated based on filtration, dilution, and disinfection.

### Involved Parties

Design engineers, facility managers, and building operations staff.

## Base Minimum

As determined in accordance with Table 6-1 in the current or relevant ASHRAE Standard 62.1, MERV 13 filters for all recirculated air. Based on the prerequisite ventilation assessment, unit motor capability and the filter manufacturer's availability must be addressed prior to filter changes. The HVAC professional should perform detailed calculations per ASHRAE guidance to account for CADR and ventilation effectiveness in the breathing zone to refine the design.

### Air Distribution

Design systems to provide well-mixed air. Avoid air velocities that create drafts or create airflow across or from one occupant to another.

### Breathing Zone

Breathing zones, as defined in the relevant or current ASHRAE Standard 62.1, should be considered when determining distribution effectiveness

### Space Total Air Changes Per Hour

To have a target CADR for the purposes of distribution and ventilation effectiveness, design engineers should strive to achieve three to six ACH minimum during occupied periods. The maximum should be based on design loads.

Reduced volume during unoccupied periods is acceptable to conform to energy code requirements.

### Air Cleaners

Consider air cleaners with HEPA filtration to supplement ventilation systems and distribution design to ensure minimum space air change CADR levels are met. This can include multiple air cleaners positioned to best provide air cleaning.

### Noise

Design systems for maximum 40 dB in classrooms.

### Equipment Motor Horsepower

Include a safety factor when sizing fan motors so the unit accommodates an increase of 25% above design external static pressure in the future.

## Advanced IAQ

### For Dedicated Outdoor Air Systems

Design the systems (equipment size and air distribution network) so they can be set to a pandemic mode of operation and deliver 30% more ventilation air than the code or base minimum. Filter ventilation air with MERV 13 filters.

### For Central Station Air Handling Systems

Design the systems (equipment size and air distribution network) so they can be set to a pandemic mode of operation and deliver 30% more ventilation air than the code or base minimum. Filter all outdoor air and recirculated air with MERV 13 filters.

Design units with 100% outside air economizers so units can provide 100% ventilation during times of the year when outside conditions can meet the HVAC loads in the building and maintain thermal comfort.

Space total air changes per hour: six to eight ACH.

### Air Cleaners

Consider air cleaners with HEPA filtration to supplement ventilation systems and distribution design to ensure the minimum space air change CADR levels are met. This should include an air cleaner positioned above the teacher’s desk or area the teacher should occupy the most during a class.

## Additional Guidance

ASHRAE. 2022. ASHRAE Standard 62.1-2022, *Ventilation and acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

Hear-it.org. 2022. School noise detrimental to hearing and learning. https://www.hear-it.org/school-noise-detrimental-hearing-and-learning.

# Classroom-Level Air Cleaning

## Overview

Air cleaners are intended to work with building ventilation systems and are not to be used as a substitute for building ventilation. While they may assist in removing infectious particles, they can present additional challenges and risks in the space.

### Benefits

The use of in-room air cleaners (either portable or permanently installed) may help reduce concentrations of airborne particulate, including airborne pathogens, from occupied spaces. In-room air cleaners utilizing HEPA filtration may effectively remove nearly all airborne pathogens passing through the unit filter

### Concerns

While in-room air cleaners are likely to help reduce airborne pathogen concentrations, they also have implications for operations in the spaces served. Sound power levels, potential negative impacts to space air distribution effectiveness, maintenance personnel safety, and maintenance requirements all need to be considered.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

## Base Minimum

Target code-required ventilation (ASHRAE Standard 62.1 requirements or equivalent), good air distribution, and increased filtration efficiency.

### Design Considerations

For buildings achieving the minimum actions above, addition of in-room air cleaners may be considered on a case-by-case basis to achieve the owner's defined level of risk tolerance. Each type of classroom use case should be included in the design of air cleaners that will accommodate the peak occupancy. For example, music rooms and conference rooms should be evaluated for higher air cleaner deployments.

### Limited or No Existing Mechanical Ventilation

In cases where there is limited or no existing mechanical ventilation, provide in-room air cleaners to provide maximum non-infectious air delivery equivalent (NIADE) rate. Consideration must be given to air distribution in space, sound power levels, and maintenance procedures.

## Advanced IAQ

Introduce terminal or portable all-electric HEPA/UV machines in each classroom.

### Design Considerations

Target highest achievable NIADE rate for units that will not generate excessive noise or negatively impact space air distribution (should not create drafts that direct air across one occupant and toward others). Ensure flow patterns maximize mixing of air in classrooms.

## Maintenance Considerations

- Relevant additions to maintenance schedule and operations training.
- Develop maintenance policies for new/added equipment such as local air cleaners, humidifiers, additional filtration in mechanical equipment, etc.

## Portable Unit Specifications

- UV-C light, minimum of 1200 microwatts/$cm^2$
- HEPA filter
- Cfm adjustable from 200 to 400 cfm
- Noise sound level under NC 35
- Power 110-volt plug in

## Suggested Guidance for Portable Classroom Air Cleaner Installation and Operations

- Air cleaner location
  - Place the air cleaner in a centralized location and as close to the main building HVAC return air grilles as possible.
  - For rooms with unit ventilators or HVAC units located near the windows, place the air cleaner in the center of the room.
  - If there is noise or there are safety concerns with the electrical wires, place the air cleaner near the teacher. Generally, adults can generate more infectious particles than children under 14.
  - Make sure the airflow pattern is one way, from occupants to return air. We want to minimize the recirculation of air amount occupants.
  - Location should be adjusted as the classroom furniture is reconfigured. Place the air cleaner near the maximum number of students.
- Air cleaner speeds during class
  - Make sure the air cleaner meets the classroom acoustics requirement and does not hamper the students' ability to hear the teacher.
  - Units have adjustable speeds. Utilize the lower speeds if there are acoustical issues; otherwise, operate at maximum acoustically suitable speed.
  - Turn on units at maximum speed one hour before any occupied event or start of class.
  - If there are any noticeable smells from cleaning products, run the units until the smell dissipates. Cleaning products can increase the level of TVOCs, which can be harmful at high concentrations.
  - Ensure unit placement will not cause additional interaction between occupants and the equipment.
- Air cleaner speeds after class
  - Air cleaner should be running at the full speed allowed during class break and between classes for a minimum of 10 minutes.
  - Turn units off one hour after space is cleaned or is unoccupied.
  - Operate units at maximum speed after class.
- Air cleaner operations for weekends

- Keep units off during unoccupied times (i.e., weekends) unless TVOC levels are high.
- Turn air cleaners on one to two hours prior to class occupancy on Mondays, if possible, at maximum speed.

## Additional Guidance


Allen, J., J. Cedeno-Laurent, and S. Miller. 2020. Harvard-CU Boulder portable air cleaner calculator for schools v1.3. https://docs.google.com/spreadsheets/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/edit#gid=1882881703.

ASHRAE. 2021. ASHRAE position document on filtration and air cleaning. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/about/position%20documents/filtration-and-air-cleaning-pd-feb.2.2021.pdf.

ASHRAE. 2021. In-room air cleaner guidance for reducing Covid19 in air in your space/room. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/in-room-air-cleaner-guidance-for-reducing-covid-19-in-air-in-your-space-or-room.pdf.


# Restroom Exhaust and Air Filtration Upgrades

## Overview

Restrooms present a challenge and risk in most schools. With the configuration of most restrooms, it is not possible to maintain social distancing requirements and the spaces are higher traffic.

When a cohorting strategy is applied, restrooms are often overlooked, though they are used by all groups, presenting a risk of transmission between otherwise isolated groups.

Additionally, toilet flushing and other activities may generate aerosols that may convey infectious particles. Due to the increased risk in these locations, there may be additional consideration warranted to mitigation.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

## Base Minimum

- Ensure that all washroom fans are operating correctly and confirm that air volumes are in accordance with ASHRAE Standard 62.1.
- Ensure that washroom exhaust systems are operating continuously during occupied periods and before and after the primary occupancy period.
- Ensure that doors opening and closing will not negatively impact airflows in the washroom. This is relevant where the washroom depends on transfer air.

## Advanced IAQ

- Consider application of upper UVGI systems such as recirculating troffer style systems and passive upper air UVGI.

- Consider using air cleaners to achieve two additional air changes in bathrooms.
- Consider using particulate sensors.
- Consider expanding exhaust ductwork grilles to be placed above each water closet. Where possible, installing grilles in the wall closer to the fixture and breathing zone is preferred but may not be possible in many locations.
- Consider increasing exhaust rates to 15% above 62.
- Consider lowering water closet partitions to floor.
- Consider touchless plumbing fixtures.

## Additional Guidance

ASHRAE. 2022. ASHRAE Standard 62.1-2022, *Ventilation and acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

# Staff Training and Documentation Organizational Platform

## Overview

A dedicated school system-level program for IAQ should be established. A maintenance and operational sequence must be adopted and strictly followed to ensure pathogen mitigation efforts and general IAQ objectives are maintained. Safety and health of all staff and students should be the fundamental basis for all maintenance schedules. All maintenance procedures, schedules, adjustments, repairs, upgrades, and replacements should be documented to provide transparency for all stakeholders.

### Stakeholders

The maintenance should be assigned to a skilled, trained, and certified workforce. The building automation system (BAS), if applicable, should include data logging and summary reports to identify issues and make energy efficiency improvements that do not degrade performance. However, all staff should be aware of the agreed upon operational plans of the facility to ensure the designed benefits are achieved.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

## Base Minimum

### Safety and Risk

All maintenance procedures should be evaluated for safety, given site-specific equipment and associated safety concerns. Added safety procedures should be in alliance with OSHA.

### Develop a Primary Maintenance Schedule

ASHRAE Standard 62.1, Chapter 8, Operations and Maintenance, provides the minimum maintenance activity and frequency for ventilation system equipment and associated components.

## Advanced IAQ

### Develop a Comprehensive IAQ and Risk Mitigation Program

Similar to water quality testing, an air quality testing and monitoring system should be established. Each jurisdiction should base their IAQ and risk mitigation program on the goals of "good" air quality in their local region. The program profile should account for outdoor contaminants as well as indoor pollutants. The program should establish HVAC upgrades as part of the capital planning effort to build systems to improve the air quality in the classroom environment. These systems should consider increased ventilation, better air filtration, better distribution of clean air, air cleaners, and continuous monitoring.

### Develop a Comprehensive Maintenance Schedule

ASHRAE Standard 180 establishes minimum HVAC inspection and maintenance requirements that preserve a system's ability to achieve acceptable thermal comfort, energy efficiency, and indoor air quality in new and existing commercial buildings. All maintenance personnel should consult ASHRAE Standard 180 to develop a detailed site-specific plan.

Acceptable IAQ parameters should be developed in collaboration with your HVAC professional and relevant authorities having jurisdiction.

## Additional Guidance


ASHRAE. 2018. ASHRAE Standard 180-2018, *Standard practice for inspection and maintenance of commercial building HVAC systems*. Peachtree Corners, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/ashrae-180-2018?product_id=2016639.

ASHRAE. 2022. ASHRAE Standard 62.1-2022, *Ventilation and acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2.

ASHRAE Epidemic Task Force. 2021. Schools & universities. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf.

NEMI. 2022. Ventilation verification specification. https://www.nemionline.org/ventilation-verification-specification/.

OSHA. 2022. Personal protective equipment. https://www.osha.gov/personal-protective-equipment.

# UV-C/UVGI in Air Handling Equipment

## Overview

UVC/UVGI equipment has been shown to be very effective in deactivating viruses and other infectious agents. These systems produce light that may be harmful to occupants, so they should be installed such that they will not affect the occupants whether being installed inside an air handler, in the upper air zone of the room, or in a recirculating configuration.

Properly sized and installed UVC/UVGI equipment may act as a supplemental factor in the room's clean air delivery, but it is important that it not replace proper outside air ventilation as defined in ASHRAE Standard 62.1.

UVC/UVGI needs to be serviced regularly to ensure that the bulbs stay clean and have not been affected by changes in temperature. The expected service life of many of the bulbs will require regular changes, so access and cost should be considered along with the additional heat generated by the lamps themselves. As more LED technology is developed, it is likely that the cost and maintenance costs of the equipment will be reduced.

### Involved Parties

Design engineers, facility managers, and building operations staff.

## Base Minimum

- Consider UV-C/UVGI in spaces that have high occupancy/frequent changeover where it may not be practical to achieve recommended air volumes.
- UV-C/UVGI should be designed in coordination with a professional to ensure the proper level of disinfection is occurring based on the airspeed and UV-C intensity of airside equipment.
- Provide a UVC fan motor interlock to energize UV-C only when the fan is operational.
- Provide a UV-C and access door safety interlock. UV-C should de-energize when door is opened for service.
- Create a dedicated UV-C installation schedule with the following minimum specified requirements:
    - AHU tag
    - Location
    - Peak airflow
    - Air velocity
    - Cross sectional area
    - Distance required
    - Distance available
    - System type
    - UV-C dose @ day 365($\mu$W-sec/cm$^2$)
    - UV-C intensity @ day 365($\mu$W/cm$^2$)
- Service considerations should be reviewed on each installation to allow for proper maintenance.

## Advanced IAQ

- Install UVC/UVGI in recirculated air systems.
- Install high air UVGI in higher volume spaces.

## Additional Guidance


ASHRAE. 2015. ASHRAE position document on filtration and air cleaning. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/about/position%20documents/filtration-and-air-cleaning-pd-feb.2.2021.pdf.

For further resources on UVC use, refer to the following:

- International Ultraviolet Association (IUVA)
- U.S. Environmental Protection Agency (EPA)
- Research Triangle Institute (RTI)

ASHRAE. 2016. Chapter 17, Ultraviolet lamp systems. *ASHRAE handbook—HVAC systems and equipment*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/i-p_s16_ch17.pdf.

ASHRAE. 2019. Chapter 62, Ultraviolet air and surface treatment. *ASHRAE handbook—HVAC applications*. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/i-p_a19_ch62_uvairandsurfacetreatment.pdf.

ASHRAE. 2020. ASHRAE position document on indoor air quality. Peachtree Corners, GA:ASHRAE. https://www.ashrae.org/file%20library/about/position%20documents/pd_indoor-air-quality-2020-07-01.pdf.

ASHRAE. 2022. ASHRAE positions infectious aerosols. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/about/position%20documents/pd_-infectious-aerosols-2022.pdf.

ASHRAE. 2020. ASHRAE Standard 185.1-2020, *Method of testing UV-C lights for use in air-handling units or air ducts to inactivate airborne microorganisms*. Peachtree Corners, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/ashrae-185-1-2020?product_id=2185612.

ASHRAE. 2020. ASHRAE Standard 185.2-2020, *Method of testing ultraviolet lamps for use in HVAC&R units or air ducts to inactivate microorganisms on irradiated surfaces*. Peachtree Corners, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/ashrae-185-2-2020?product_id=2185696.

Bahnfleth, W.P. 2020. Reducing infectious disease transmission with UVGI. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/professional%20development/learning%20portal/instructor-led%20training/online%20instructor-led/final-4-21-2020-ashrae-one-hour-uvgi-course_secured.pdf.

Illuminating Engineering Society. 2020. Guidance on the use of ultraviolet germicidal irradiation (UVGI) in museum applications. IES WP-1-20. New York: IES. https://store.ies.org/product/wp-1-20-ies-white-paper-guidance-on-the-use-of-ultraviolet-germicidal-irradiation-uvgi-in-museum-applications/.

# Medium Priority Tasks

## Humidification and Dehumidification Systems

### Overview

Consider maintaining relative humidity (rh) at 40% to 60%. Optimal relative humidity continues to be an area of active research. Dry air below 40% rh has been shown to:

- Reduce healthy immune system function (respiratory epithelium, skin, etc.).
- Increase transmission of some airborne viruses and droplets (COVID-19 still being studied).
- Increase survival rate of pathogens.
- Decrease effectiveness of hand hygiene and surface cleaning because of surface recontamination or disinfectants drying too quickly.

#### Concerns

If restarting older humidifiers, take care to confirm proper moisture absorption in the airstream.

Visually inspect humidification and dehumidification devices. Clean and maintain to limit fouling and microbial growth. Measure relative humidity and adjust system controls as necessary per ASHRAE Standard 62.1 Table 8-1 (g).

Watch interior spaces to confirm no condensation is occurring, which would permit mold and moisture issues. Reducing economizer operation is not recommended to improve minimum rh if it means losing negative pressure in rooms or losing once-through airflow if those strategies are part of the surge plan.

Ensure adequate maintenance capacity and water treatment is available to safely operate humidifying equipment.

#### Involved Parties

Design engineers, facility managers, and building operations staff.

### Base Minimum

#### Design Considerations

Indoor relative humidity is a function of seasonal climate and building HVAC. The range of 40% to 60% rh may reduce contagion and help those who are infected. Summer classroom design guidelines: 75°F (24°C)/40% to 60% rh. Primary guidance is to design to 50% rh in summer, depending on the classroom system.

During periods of time that the building is both occupied and unoccupied, it is recommended that maximum humidity levels are addressed to not cause damage to building materials that may be subject to damage at high humidity levels.

Consider monitoring the humidity levels in a few classrooms within the building. Ensure that humidification systems do not generate an increase in particulate matter.

## Advanced IAQ

### Design Considerations

Winter classroom design guidelines: 72°F (22°C)/40% to 50% rh. Primary guidance in winter is 40% to 50% rh via humidifiers/active humidification (central or local, depending on the classroom/space system). The humidity minimum, humidifier, and sensor location should be made after consideration of envelope design due to the potential for condensation within the building envelope.

The levels of 40% rh may be difficult to achieve in northern colder climates without formation of condensate on glazing or within the building envelope. Review of the building envelope design is crucial to ensure that damage to the building envelope will not be created.

Summer classroom design guidelines: 75°F (24°C)/40% to 60% rh.

# Energy Efficiency Offset Control Schemes for Advanced IAQ

## Overview

Generalizing for most HVAC systems, with the increase of more ventilation air, except for economizer mode, it is sufficiently likely to expect higher energy usage. As advanced air quality centers around maximizing the ventilation air and disabling demand control ventilation systems, the logical result will be increased energy to condition the increased outside air being brought into the building in both the heating and cooling season.

With 8760 hours in a year, the best approach for energy efficiency during the period of increased ventilation rates is to focus efforts on unoccupied times. In some schools, this will be 6000+ hours per year. The energy efficiency programs put in place should not diminish the indoor air quality by adverse ventilation scheme changes.

### Involved Parties

Design engineers, facility managers, building operations staff, and building controls staff.

## Base Minimum

Building management system with all HVAC and lighting integrated.

- Focus on unoccupied hours and adjusting sequences to move to minimal energy usage during unoccupied times.
- Air cleaners for occupied mode operations in lieu of increasing ventilation rates.
- Wider temperature bandwidth ranges for occupied zones 5% outside of ASHRAE Standard 62.1.

- Adjust the discharge temperatures from central air handling stations based on the specific climate zone within 2% of ASHRAE Standard 62.1.

## Advanced IAQ

- Building management system with all HVAC, plumbing, equipment, and lighting integrated.
- Focus on unoccupied hours and adjusting sequences to move to minimal energy usage during unoccupied times.
- Air cleaners for occupied mode operations in lieu of increasing ventilation rates.
- Wider temperature bandwidth ranges for occupied zones 10% outside of ASHRAE Standard 62.1.
- Adjust the discharge temperatures from central air handling stations based on the specific climate zone within 3% of ASHRAE Standard 62.1.
- Enhanced air quality mode can be implemented into control systems. This mode will revise $CO_2$ set points, run times, and system operation in accordance with enhanced air quality parameters. This mode can be quickly activated with one button during periods of elevated pathogen risk. Alarms can be configured to occur on a regular basis to ensure that the mode is not left on beyond the intended time frame.
- Incorporate exhaust air heat recovery.

## Additional Guidance


ASHRAE. ASHRAE advanced energy design guide—Achieving zero energy series. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download.

ASHRAE. 2021. ASHRAE Guideline 36-2021, *High performance sequences of operation for HVAC systems*. Peachtree Corners, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/guideline-36-2021-high-performance-sequences-of-operation-for-hvac-systems?product_id=2229690.

ASHRAE Epidemic Task Force. 2022. Building readiness. Peachtree Corners, GA: ASHRAE. https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf.


# Operable Windows

## Overview

Any operable window usage for natural ventilation needs to be addressed and agreed upon with your HVAC professional. Operable windows may be used to supplement mechanical ventilation, or when no mechanical ventilation exists, natural ventilation should be considered with an understanding of limitations. While operable windows by themselves will not provide consistent ventilation rates, there are steps that may be added to improve the ventilation consistency.

Natural ventilation requires either an automated system that is maintained by facilities or a highly trained staff to consistently open and close windows during scheduled times.

### Concerns

- Security
- Noise
- Consistency—Natural ventilation rates are dependent on several factors including pressure and temperature differentials.
- Seasonal Consistency—Occupants will be inclined to close the windows during seasonal high and low temperature fluctuations.
- Contamination
- Air Distribution
- Humidity

The best operational control of window opening criteria is to use a BMS with dew point criteria if relevant to local climatic conditions. There should also be provisions for the individual classrooms to have alarms or alerts to close the windows based on dew point or other local criteria. In the absence of these automated controls, please follow the instructions below if the school system is allowing the teachers to open their windows based on their own personal preference.

### Involved Parties

Design engineers, facility managers, architects, and building operations staff.

## Base Minimum

### Natural Ventilation

Natural ventilation should be performed in accordance with the corresponding section within the adopted mechanical code or regional requirements—UMC Section 402.2 or 402 IMC.

### Negative Pressure

To provide a more consistent ventilation rate, the classroom can be operated at a negative pressure, relative to the outside. With common windows open, either manual or automatic, an outside air rate can be introduced. If the classroom is independent of other structures, the ventilation rate can be consistent if the same number of windows are opened during operation. If the classroom is attached to other buildings, the exhaust will pull air from outside or from adjacent rooms based on the path of least resistance. A negative pressure can be introduced by adding exhaust fans or taking advantage of existing exhaust fans depending on location.

### Develop Manual Window Opening Guideline

Based on regional climate and safety considerations, the guide below may be used as a starting point with school officials.

Classroom windows may be manually opened during class per the following general guidelines during reopening operations.

- Outside temperatures between 50ºF (10°C) and 90°F (32°C): Windows can be opened.

    - HVAC units that are controlled by temperature will automatically adjust. At lower temperatures, there will be excess running of units during occupied hours.
    - Close windows during unoccupied hours and let HVAC systems run per schedule.
- Outside temperatures between 35°F (1.7°C) and 50°F (10°C): Windows may be opened for 15 minutes each hour during occupied times.
    - Close windows when unoccupied.
    - If the classroom starts to feel too cold, adjust to 5–10 minutes open per hour.
- Outside temperatures below 35°F (1.7°C):
    - Windows can be opened at 50% for 15 minutes every 2 hours.
    - If classrooms have no fresh air, open windows at 50% every 15 minutes every hour. Monitor any water piping and sprinkler piping for freeze potential.
    - If the classroom starts to feel too cold, adjust to 5–10 minutes open per hour.
    - Classroom windows MUST be closed during unoccupied hours and weekends.
- Close windows if it is raining or is a humid day to prevent any mold growth.

## Advanced IAQ

- Automated natural ventilation systems may be considered to provide consistent open times. Advanced systems may be linked to a variety of indoor and outdoor climate sensors.
- Occupant indicators may be provided to indicate to occupants that the windows should be open.
- Security indicators may be useful to ensure that windows are closed. This may be accomplished with the addition of end switches on the windows to verify that they are closed.