DESIGN GUIDANCE FOR EDUCATION FACILITIES: PRIORITIZATION FOR ADVANCED INDOOR AIR QUALITY

TC 9.7 - Educational Facilities Working Group

Primary Contributing Authors: Raj Setty P.E., CxA, LEED AP, Christopher Ruch, Corey Metzger P.E., Kyle Hasenkox, Keith Hammelman P.E., Itzhak Maor P.E., PhD

ASHRAE TC 9.7 is concerned with the application of heating, ventilating, air-conditioning, refrigeration, life safety, and energy conservation systems to educational facilities.

Document Intent and Scope:

The scope and intent of this document is to provide guidance to Owners, Operators, Designers, and Professional Service Providers on how to best implement Indoor Air Quality (IAQ) improvements, including risk mitigation strategies, in educational facilities. The guide will also help facilitate discussion between designers and stakeholders, identify minimum recommendations and discuss further considerations to improve IAQ and reduce the risk of transmission of infectious pathogens and other contaminants of concern.

Table Of Contents:

Prioritization for Advanced Indoor Air Quality: Check List

Complete	PRE-REQUISITE TASKS
	Ventilation Verification and Testing, Adjusting and Balancing (TAB) of HVAC airside components
	Risk Tolerance Assessment – Wells-Riley or Equivalent

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 recommended ASHRAE 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 systems
		Energy Efficiency offset control schemes for Advanced Indoor Air Quality
		Operable Windows

Purpose

This design guide should be used to prioritize decisions related to Heating, Ventilating, and Air Conditioning (HVAC) system design and operation for both existing facilities (commissioning, maintenance, improvement, and retrofit projects) and new facilities in order to improve indoor air quality while limiting energy consumption.

Indoor Air Quality (IAQ) upgrades can both improve learning outcomes and mitigate the risk of transmission of airborne pathogens within the educational environment.

The document shall help qualified professionals, including HVAC engineers, commissioning agents, testing and balancing providers, and facility managers assess existing facilities and identify appropriate design decisions for new facilities. Every school and its HVAC systems are unique and require their own distinct solutions. This document provides prioritization themes but does not replace the efforts of a qualified professional in assessing the unique characteristics of each facility.

As noted in the Table of Contents, this document is broken into several groups, including Pre-Requisite Tasks, Very High Priority Tasks, High Priority Tasks, and Medium Priority Tasks. Within each of these groups, there 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 ASHRAE Technical Committee 9.7 – Educational Facilities and by 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 further 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.

PRE-REQUISITES

Establishing an Indoor Air Quality (IAQ) building level Improvement Plan is a process that involves several components. These pre-requisites 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 indoor air quality. 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 can come from record drawings, manuals, control systems, personnel interviews, or maintenance records. The initial data collection process can be shared between facility stakeholders including administrative, maintenance and operations and HVAC professionals as needed in order 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 be able to 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 shall give an estimate of the risk in specific spaces and can 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 pre-requisites to the process. While variations of these pre-requisites 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 and Testing and Balancing 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 shall be submitted to a HVAC design professional for determination of adjustments, replacements, repairs, and upgrades. Where possible this can be compared to record drawings and manuals and deficiencies in performance noted.

Involved Parties:

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:

See Hyperlinks below for Sample Ventilation Verification Assessment test sheets and Method of Procedure (MOP). Sample procedures should be altered to meet local requirements, updated recommendations, and site-specific equipment.

*www.nemionline.org/testing-adjusting-and-balancing-hvac-systems-an-overview-of-certification-agencies/

Base Minimum:

For All Airside systems:

- Document Filter MERV Values and ensure proper installation with minimum bypass air.
- Physically Verify and document Ventilation Rates.
- Physically verify Demand Control Ventilation (DCV) operates as intended. 10% sampling is acceptable for verification. If carbon dioxide used as 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 5 years.
- Air Distribution – Measure 10% of all zones/inlets/outlets for a cfm sampling. These should be representative of the overall HVAC System. Zones measured shall 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 shall be read between space of concern and adjacent occupied area(s).
- Document existing Sequence of Operations (SOP/SOO) and Operational Controls.
- Document ambient outdoor CO2 conditions and differential to indoor spaces. Trend the CO2 levels over the duration of peak occupancy. If CO2 Levels exceed recommended limits (typically outside air level +750 ppm set point or 1100-2000 ppm) for 90 minutes, then further recording should be implemented. Recommended limits are based on ASHRAE TC 9.7 members design experience.
- Perform Testing of PM2.5, PM10 and VOC levels in 10% of spaces over a minimum period of 1 week.
- Verify that equipment is operating as outlined in the SOP/SOO.
- Report and remediate any issues and coordinate with the design professional.

Exhaust:

- Air Distribution – survey 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 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.
- Physical verification of ability to increase ventilation above scheduled value.
- Physically verify the ability to override and/or disable the DCV.
- Air Distribution – Measure 100% of all inlets/outlets.
- Document building pressure relationships of all rooms as recommended by your HVAC professional.
- Test 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:

- Air Distribution – survey 100% of all exhaust inlets for a sampling.

Hyperlinks:

- **Sample Ventilation Verification Assessment Test Sheets and Method of Procedure (MOP)**
- Sample **Ventilation Verification Specification**
- **Technical Paper - Overview of TAB Certification Agencies.**
    - Associated Air Balance Council (AABC)
    - National Environmental Balancing Bureau (NEBB)
    - Testing Adjusting and Balancing Bureau (TABB)
- **UC Davis Film - Ventilation in Schools**
- **White Paper on Proposed School Ventilation and Efficiency Verification and Repair Program**
- International Airborne Pollutant Standards/Requirements
- **ASHRAE TC 7.7**

Risk Tolerance Assessment – Wells-Riley or Equivalent

Overview:

When prioritizing IAQ projects and budgeting, start with a baseline of the current probability of infection. Then establish a target goal for the probability of transmission of infectious airborne assessments, based on HVAC and operational changes. A risk assessment must be performed as part of the basis of design for any IAQ upgrade project.

Designers and Engineers need to evaluate their design approaches for effectiveness in reducing the risk of transmission. The calculation tool can be used to compare HVAC options against each other to balance effectiveness and budgetary constraints.

It is recommended that the stakeholders determine the acceptable level of risk as defined by their governing bodies.

Involved Parties:

Design Engineers, Facility Managers, Architects, Building Operations Staff, Local Health Officials.

Base Minimum:

While there are no 100% solutions to ensure no one will be infected by a virus in a common space like a classroom, there are operational and HVAC system changes that will reduce the airborne concentration of viruses. The underlying directive for HVAC engineers is to "Do No Harm". The application of better filtration, reduction in exposure time, reduction in occupancy, more fresh air to the building spaces and disinfection of the airstream via UV-C all have positive impacts to the indoor air quality. While there are cost implications to the various applications, the risk of negatively impacting the indoor air quality is almost negligible.

Below are some examples of risk analysis tools available. The site-specific strategy employed should be developed in collaboration with stakeholders and your HVAC professional.

- 2020_COVID-19_Aerosol_Transmission_Estimator
- COVID-19-Self-Assessment-Calculator-for-Higher-Education
- Harvard-CU Boulder Portable Air Cleaner Calculator for Schools.v1.3
- SETTY+5.2+Airborne+Transmission+Infection+Rate+Estimator

Note: These calculators are examples of risk assessment tools and are not an endorsement of the tool itself.

Wells-Riley Equation

$$P_{\text{infection}} = 1 - e^{-\frac{pIq}{V} \times \frac{Ct + e^{-Ct} - 1}{C^2}}$$

P Infection is the probability of infection
C is the number of infection cases
S is the number of susceptible
I is the number of infectors
p is the pulmonary ventilation rate of a person
q is the quanta generation rate (based on the estimated epidemiologically outbreak use case)
t is the exposure time interval
V is the volume of the room
Q is the room ventilation rate with clean air.

Advanced IAQ:

Advanced IAQ risk assessments should address both the probability of infection as well as air cleaning strategies. Advanced IAQ assessments should also address specific airborne containments beyond the base IAQ risk assessments. The site specific strategy employed should be developed in collaboration with stakeholders and your HVAC design professional. Advanced IAQ risk assessments should employ a layered mitigation strategy to reduce the probability of containment transmission.

Wells–Riley model (Fisk et al., 2005; Nazaroff et al., 1998): for particle removal and air disinfection (UV-C, UVGI)

Add to the equation

λ UV is rate coefficient of inactivation by ultraviolet irradiation

Q r is the flow rate to the filter

η r is the filtration efficiency

Hyperlinks:

- **Sze and Chao, Review and comparison between the Wells–Riley and dose-response approaches**
- **EPA - Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure (IAQX)**
- **NIST ViPER - Virus Particle Exposure in Residences Tool**
- **Bahnfleth, Reducing Infectious Disease Transmission with UVGI**

VERY HIGH PRIORITY TASKS

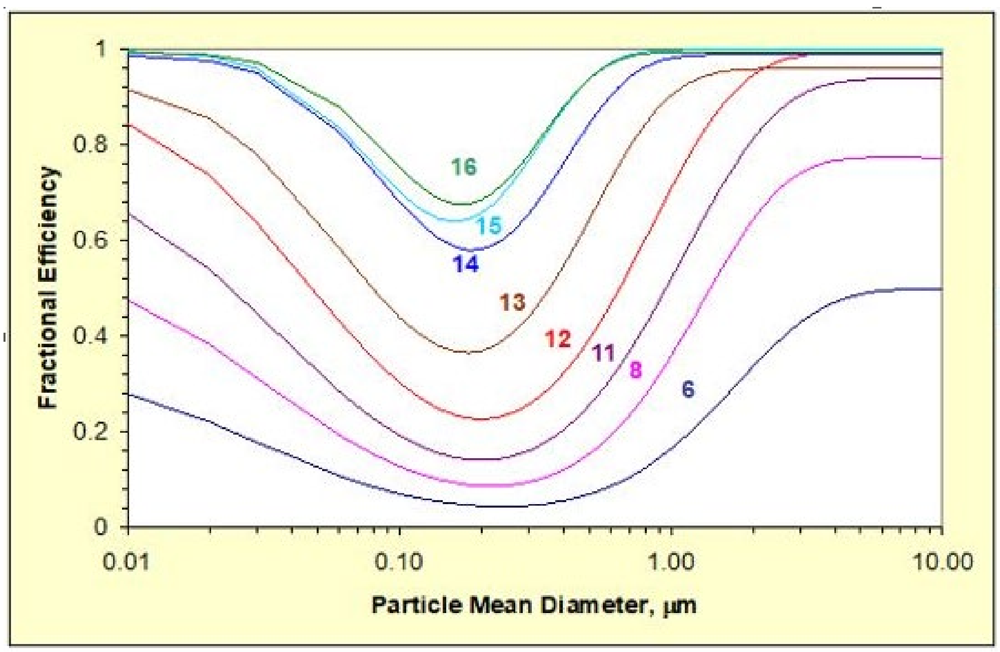
HVAC Equipment Filtration Upgrades

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 as 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 but from research, but it has been determined that MERV 13 to MERV 14 filter ratings is where diminishing returns begin in the effectiveness of particles being removed.

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 professional to handle the filter upgrade. If the filter frame cannot be increased, then proceed with the highest-level MERV filter that will not require the equipment or ductwork to be changed. With the introduction of new filters there may be higher O&M and energy costs plus a higher pressure drop which should be reviewed for impacts by your HVAC professional.



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

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 Minimum Efficiency Reporting Value (MERV) filter for the HVAC units (local, central and DOAS) given limitations with increase pressure drop. MERV 13 is the recommended minimum.
- Create and follow safe procedures for filter maintenance and operations per 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.
- All filters should be clearly labelled by the manufacturer 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 Building Readiness Document for additional guidance).
- Consider having the Facility Staff who does filter change-out to be trained for proper installation and maintenance of new filters and air cleaning systems.

Hyperlinks:

- **United States EPA – What is a MERV Rating?**
- **UC Davis Film – The Importance of Filtration in Schools**
- **ASHRAE Standard 52.2 2017 – Method of Testing General Ventilation Air-Cleaning Devices for Removal of Efficiency by Particle Size**
- **ASHRAE Epidemic Task Force – Filtration & Disinfection**

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

Overview:

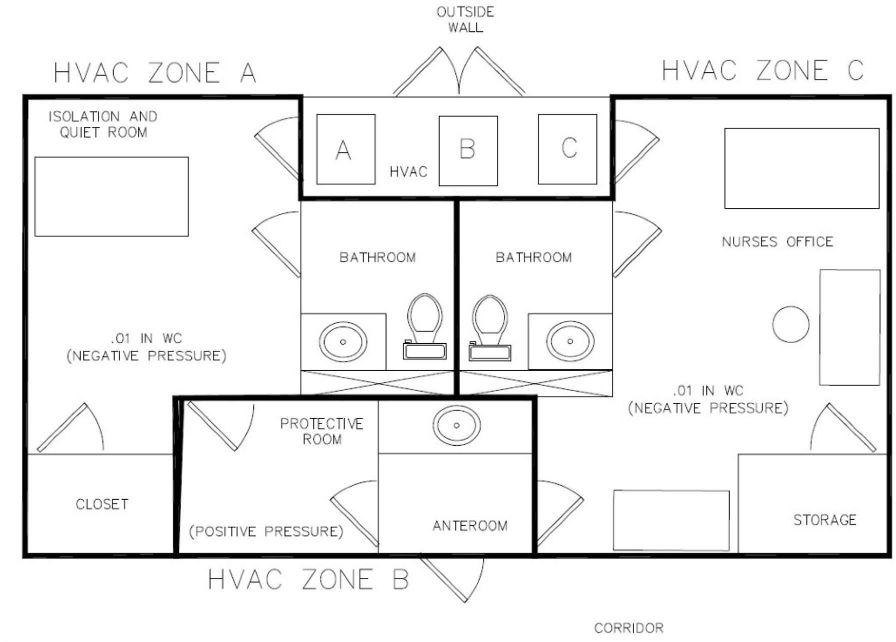
This section is about the Wellness/Nurse Suite section of an educational facility where students with medical issues are placed during the period prior to them being transferred out of the facility. It is intended to be a transitory space to temporarily hold potentially infectious persons. Due to the operation of many facilities, this space is often located at or near the central office which also acts in a security role 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 size of facility 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 with 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 please refer to ASHRAE Standard 170 or appropriate standard. Due to an 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 both 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 safety and protection of the attending nurse or staff needs to be accommodated in the design approach. When locating a nurse's isolation suite, the safe and efficient movement of a sick person from the nurse's suites out of the building needs to be considered to minimize the release of pathogens in the building.



*ASHRAE Epidemic Task Force for Schools & Universities

Involved Parties:

Design Engineers, Facility Managers, Architects, Building Operations Staff.

Base Minimum:

- Wellness/Nurse office or suite (any space intended for occupancy by individuals who are sick or suspected to be sick) shall 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 shall be exhausted to outdoors. Exhaust air may pass through energy recovery devices serving other building areas being exhausted, so long as systems comply with ASHRAE Standard 62.1. Exhaust air intakes shall be fully ducted to intakes in space.
- Air recirculated within the space shall be filtered through filter media with minimum MERV rating of 13.
- Maintain a minimum air change rate to space of 6 total Air Changes per Hour (ACH) and minimum of 2 ACH of outdoor air. All the air in the waiting areas and the isolation room will 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 the isolation rooms will depend on the school programing requirements.
- Do not mix supply air and return air from isolation room with any other spaces when in isolation mode.
- Maintain a minimum clean air change rate (ACH) of 6 in all conditioned spaces in the nurse suite, 10 ACH in the waiting room and 12 ACH in the isolation room(s). All the air in the waiting areas and the isolation room will be exhausted when building or space is occupied.
- Exhaust directly to outdoors. Follow ASHRAE 62.1 requirements to avoid re-entrainment of contaminated air. If there is a concern of recirculation, then HEPA filtration on exhaust could be added.
- Nurse's suite should be under negative air pressure in relation to building corridors and adjacent spaces.
- Follow applicable ASHRAE Standard -170 -2021 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 become contaminated.

Advanced IAQ:

- Create a 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/carry over in the energy recovery heat exchanger). The unit will 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 170 and 2019 ASHRAE Handbook Chapter 9.
- 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 room.
- Dedicated bathrooms which 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 one (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 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, TVOC, PM2.5 and PM10 should be monitored.

Hyperlinks:

- **ASHRAE Reopening of Schools and Universities**
- **ASHRAE Standard 170 - Ventilation of Healthcare Facilities**
- **Infection Control Checklist for Risk Assessment and Precautions for Construction**
- **ASHRAE Standard 62.1 - Ventilation for Acceptable Indoor Air Quality**

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 it 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 shall ensure are no direct drafts that could concentrate infectious aerosols.

By maintaining good mixing, it will also reduce thermal stress and conform to energy standards such as ASHRAE 90.1 v 2016 and later for discharge air temperature requirements.

Involved Parties:

Design Engineers, Facility Managers, Architects, 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 system follow ASHRAE 90.1 v2016 and later which limit discharge temperature to 20F above room temperature.
- Design intent should minimize crossflow between occupants but maximize room volume dilution.
- Minimum outside air shall not be substituted with increased ventilation effectiveness strategies.
- Review temporary dividers impacts 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 of temperature difference between the head and foot level of the space and air velocity.
- ASHRAE wants 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 Indoor Air Quality but their impact on existing distribution effectiveness shall be reviewed.
- CFD modelling can be used to consider different approaches and model various classroom configurations and desk arrangements.

Hyperlinks:

- **ASHRAE Standard 90.1 - Energy Standard for Building Except Low-Rise Residential Buildings**
- **ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy**

HIGH PRIORITY TASKS

IAQ Sensors with Data Aggregation Platform

Overview:

Indoor air quality (IAQ) sensors distributed throughout the building will provide a baseline IAQ profile of the entire building. The goal of this section is to inform the practitioners on how to prepare sensors and interpret readings for an IAQ centric HVAC system. The driving force for our industry has been energy efficiency which has been the predominant underlying engineering design dogma. This will now need to 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 will be to deploy a suite of IAQ sensors to provide a data driven approach to proper HVAC operations.

The designer must at a minimum evaluate PM2.5/1.0/0.5, CO2, temperature, TVOC's 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 6 months of data collection through both occupied and unoccupied times. Sensors should be UL 2905 Compliant.

Involved Parties:

Design Engineers, Facility Managers, Architects, 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 CO2, TVOC's and PM levels. Thresholds should incorporate time elements and be established on local outdoor air quality as the baseline.
- Monitor PM2.5, CO2, temperature, TVOC's, humidity.
- Establish an on-going testing and verification program as per table 8.1 in ASHRAE 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 CO2 sensors. A sensor failing to meet the accuracy specified in the O&M manual shall be recalibrated 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 sf.
- 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 PM2.5, CO2, temperature, TVOC's, humidity levels of degradation from peak occupancy to baseline normal levels. HVAC should be capable of adjustments to increase 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 air flow 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 PM10, PM1.0, 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, then maximize outdoor air.

Hyperlinks:

- **CDC - NIOSH Pocket Guide to Chemical Hazards**
- **AIRNOW - Air Quality Index (AQI) Basics**
- **EPA - Creating Healthy Indoor Air Quality in Schools**
- **ASHRAE Standard 62.1 - Ventilation for Acceptable Indoor Air Quality**
- **UC Davis Film - Ventilation in Schools**
- **International Airborne Pollutant Standards/Requirements**

New HVAC Equipment to Achieve Recommended ASHRAE 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 as determined using the prescriptive table 6.-1 in ASHRAE Standard 62.1 -Ventilation for Acceptable Indoor Air Quality, 2019.

Involved Parties:

Design Engineers, Facility Managers, Building Operations Staff.

Base Minimum:

As determined in accordance with Table 6-1 in ASHRAE Standard 62.1-2019:

MERV 13 filters for all recirculated air.

Air Distribution:

Design systems to provide well mixed air.

Avoid air velocities that create drafts or create air flow across or from one occupant to another.

Space Total Air Changes Per Hour

- 3 to 6 ACH minimum during occupied periods. Maximum shall 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 the 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 that the unit accommodate an increase of 25% increase 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 that 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 that 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 that 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

- 6 to 8 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 cleaners positioned above the teacher's desk or area the teacher shall occupy the most during a class.

Hyperlinks:

- **ASHRAE 62.1 - Ventilation for Acceptable Indoor Air Quality**
- **Hear-it – School Noise Detrimental to 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 can assist in removing infectious particles, they can present additional challenges and risks into the space.

Benefits:

The use of in-room air cleaners (either portable or permanently installed) can help to reduce concentrations of airborne particulate, including airborne pathogens, from occupied spaces. In-room air cleaners utilizing HEPA filtration can 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, and maintenance personnel safety and maintenance requirements all need to be considered.

Involved Parties:

Design Engineers, Facility Managers, Architects, 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 Owner's defined level of risk tolerance. Each type of classroom use case should be included in the design of air cleaners which 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:

a) UV-C light – a minimum of 1200 microwatts/cm^2
b) HEPA filter
c) CFM adjustable from 200 cfm to 400 cfm

d) Noise sound level under NC 35
e) Power 110-volt plugin

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.
  - For rooms with unit ventilators or HVAC units located near the windows, place the air cleaner in the center of the rooms.
  - If noise or there are safety concerns of 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 re-circulation of air amount occupants.
  - Location should be adjusted as the classroom furniture is re-configured. Place 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 ability of students to hear the teacher.
  - Units have adjustable speeds and utilize the lower speeds if there are acoustical issues, otherwise operate at maximum acoustically suitable speed.
  - Turn on units 1 hour before any occupied event or start of class at maximum speed.
  - If there are any noticeable smells from cleaning products, then run the units until the smell dissipates. Cleaning products can increase the level to Total Volatile Organic Compounds which at high concentrations can be harmful.
  - Ensure unit placement will not cause additional interaction between occupants and the equipment.
- **Air cleaner speeds after class**
  - Air cleaner should be running at full speed allowed during class break and between classes for a minimum of 10 minutes.
  - Turn off units 1 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 (i.e., weekends) unless TVOC levels are high.
  - Turn air cleaners on one to two hours prior to class occupancy on Monday's, if possible, at maximum speed.

Hyperlinks:

- **In-Room Air Cleaner Guidance for Reducing Covid-19 In Air In Your Space/Room**
- **Harvard-CU Boulder Portable Air Cleaner Calculator for Schools**
- **ASHRAE Position Document – Filtration and Air Cleaning**

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, the restrooms are often overlooked and are used by all groups presenting a risk of transmission between otherwise isolated groups.

Additionally, toilet flushing, and other activities can 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, Building Operations Staff

Base Minimum:

- Ensure that all washrooms' fans are operating correctly and confirm that air volumes are in accordance with ASHRAE 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 the 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 2 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.

Hyperlinks:

- **ASHRAE 62.1 - Ventilation for Acceptable Indoor Air Quality**

Staff Training and Documentation Organizational Platform

Overview:

A dedicated school system level program for Indoor Air Quality should be established. A maintenance and operational sequence must be adopted and strictly followed to ensure pathogen mitigation efforts and general indoor air quality objectives are maintained. Safety and health of all staff and students shall 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. 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, Building Operations Staff

Base Minimum:

Safety and Risk:

All maintenance procedures shall be evaluated for safety given site specific equipment and associated safety concerns. Added safety procedures shall be in alliance with the Occupational Safety and Health Administration (OSHA).

Develop a Primary Maintenance Schedule:

ASHRAE 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 monitoring and 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 cleaners, and continuous monitoring.

Develop a Comprehensive Maintenance Schedule

ASHRAE 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 180 to develop a detailed site-specific plan.

The development of acceptable indoor air quality parameters should be developed in collaboration with your HVAC Professional and relevant Authorities Having Jurisdiction.

Hyperlinks:

- ASHRAE 62.1 - Ventilation for Acceptable Indoor Air Quality
- ASHRAE Standard 180 - Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
- ASHRAE Schools Document with Checklist
- Sample Ventilation Verification Specification
- OSHA – 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 can be harmful to occupants so they need to 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 can act as a supplemental factor in the rooms 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 can be affected by changes in temperature. The expected service life of many of the bulbs will require regular changes so access and cost will need to 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 reduce.

Involved Parties:

Design Engineers, Facility Managers, Building Operations Staff

Base Minimum:

- Consider UV-C/UVGI in spaces that are 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 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(μW-sec/cm2,) and UV-C Intensity @ day 365(μW/cm2).
- 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.

Hyperlinks:

- **ASHRAE Position Documents on Indoor Air Quality**
- **ASHRAE Position Document on Airborne Infectious Diseases**
- **2019 ASHRAE Handbook – Applications, Chapter A60, Ultraviolet Air and Surface Treatment**
- **2016 ASHRAE Handbook – Systems and Equipment, Chapter S17, Ultraviolet Lamp Systems.**
- **ASHRAE Standard 185.2-2014, Method of Testing Ultraviolet Lamps for Use in HVAC&R Units or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces**
- **ASHRAE Standard 185.1-2015,Method of Testing UV-C Lights for Use in Air-Handling Units or Air Ducts to Inactivate Airborne Microorganisms**
- **ASHRAE Position Document – Filtration and Air Cleaning**
- **Refer to the International Ultraviolet Association (IUVA), Environmental Protection Agency (U.S. EPA) or Research Triangle Institute (RTI) as a further resource for UVC use**
- **IES White Paper: Guidance on the use of Ultraviolet Germicidal Irradiation (UVGI) in Museum Applications**
- **UVGI course by W. Bahnfleth – Reducing Infectious Disease Transmission with UVGI**

MEDIUM PRIORITY TASKS

Humidification Systems

Overview:

Consider Maintaining relative humidity at 40-60% RH. 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 too-quick drying of disinfectants.

Concerns:

Take care if restarting older humidifiers to confirm proper moisture absorption in the airstream.

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, 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/40%-60% RH. Designing to 50% RH in summer is primary guidance, depending on the classroom system.

During periods of time that the building is both occupied and un-occupied we do recommend that maximum humidity levels are addressed to not cause damage to building materials which 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/40- 50% RH.

40- 50% RH in winter is primary guidance 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.

Energy Efficiency Offset Control Schemes for Advanced Indoor Air Quality

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 era of increased ventilation rates will be to focus your efforts on unoccupied times. In some schools this will be 6000 hours plus per year. The energy efficiency programs put in place should and cannot diminish the indoor air quality by adverse ventilation scheme changes.

Involved Parties:

Design Engineers, Facility Managers, Building Operations Staff, 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 62.1.
- Adjust the discharge temperatures from central air handling stations based on the specific climate zone within 2% of ASHRAE 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 62.1.
- Adjust the discharge temperatures from central air handling stations based on the specific climate zone within 3% of ASHRAE 62.1.
- Enhanced Air Quality Mode can be implemented into control systems. This mode will revise CO2 setpoints, runtimes 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.

Hyperlinks:

- **ASHRAE Advanced Energy Design Guide**
- **ASHRAE Guideline 36-2018 High Performance Sequences Of Operation For HVAC Systems**
- **ASHRAE Epidemic Task Force - Building Readiness**

Operable Windows

Overview:

Any operable window usage for natural ventilation needs to be addressed and agreed upon with your HVAC professional. Operable windows can 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 can 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 constantly 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 your 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, Building Operations Staff

Base Minimum:

Natural Ventilation:

Shall be done 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 can be used as a starting point with school officials.

Guidance for opening classroom windows manually:

Classroom windows maybe opened during class per the following guidelines during the re-opening operations – these are general guidelines for the classroom.

- Outside temperatures between 50ºF and 90°F – windows can be opened.
  - HVAC units which 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 and 50°F – windows can be opened for 15 minutes each hour during occupied times.
  - Close windows when unoccupied.
  - If classroom starts to feel too cold, then adjust to 5-10 minutes open only per hour.
- Outside temperatures below 35ºF
  - Windows can be opened at 50% open for 15 minutes every 2 hours.
  - If classrooms have no fresh air, then open windows at 50% open every 15 minutes every hour. Monitor any water piping and sprinkler piping for freeze potential.
  - If classroom starts to feel too cold, then adjust to 5-10 minutes open only per hour.
  - Classroom windows MUST be closed during unoccupied hours and weekends.
- Close windows if it is raining or it is a humid day – this is to avoid any mold growth.

Advanced IAQ

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

End of Document