



Ventilation

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Objectives

- ❖ Key ventilation operations and functions
- ❖ Filtration
- ❖ Why ventilation is important and the role it plays in infections and infection control
- ❖ Air disinfection
- ❖ Basic maintenance and alternatives when system is down



Ventilation

- ❖ Supplying or removing air to a space either by natural or mechanical means for purposes that include control of contaminate levels
 - Filtered
 - Treated, temperature and/or humidity
 - Combination

- ❖ Dilute and displace contaminated air
 - Replacing/mixing with less contaminate or uncontaminated air

- ❖ Room air flow patterns greatly impact the effectiveness of ventilation



Ventilation

- ❖ Along with the room purpose, generally ventilation requirements are based on the maximum number of occupants and floor area or volume of the space as well as the activities that will be conducted in the room
 - Office cubicle
 - Intensive Care Unit

ANSI/ASHRAE Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality

Standard 62.1 specifies minimum ventilation rates and other measures intended to provide indoor air quality (IAQ) that's acceptable to human occupants and that minimizes adverse health effects. The standard provides procedures and methods for meeting minimum ventilation and IAQ requirements to engineers, design professionals, owners, and jurisdictional authorities where model codes have been adopted.

Since its original publication, Standard 62.1 has been revised and enhanced in ways that make it more than an air treatment and ventilation standard. To signify that indoor air quality goes beyond minimum ventilation requirements—and in recognition of those aspects of building systems (equipment, filtration, controls, and more) that contribute to acceptable IAQ—the title of the standard has been updated to “Ventilation *and* Acceptable Indoor Air Quality.”



Image: [Standards 62.1 & 62.2 \(ashrae.org\)](https://standards.ashrae.org), accessed 10/25/2023



Two Types of Ventilation

Dilution

- ❖ Mix fresh air with contaminated air to reduce the concentration of contaminants
- ❖ Depending on the room use, there are recommendations on how often the air in the room should be “replaced”

Local Exhaust

- ❖ Remove/exhaust contaminant from the air close to its point
 - Laboratory fume hood
 - Ventilated headboard



Patient Focused Local Exhaust



Ventilated headboard

Image: [NIOSH Ventilated Headboard Provides Solution to Patient Isolation During an Epidemic | Blogs | CDC](#), accessed 10/23/2023



Room Focused Ventilation

❖ Positive pressure rooms

- Air pressure is **higher** inside the room than outside the room so air flows out of room
- Protects the patient inside the room, keeps pathogens out of the room

❖ Negative pressure rooms

- Air pressure is **lower** inside the room than outside the room so air flows into the room
- Protects occupants outside of the room, keeps pathogens inside the room



HVAC System Functions

- ❖ Heating
 - ❖ Cooling
 - ❖ Ventilation
 - ❖ Filtration
 - ❖ Dehumidification
 - ❖ Humidification
 - ❖ Distribution
- ❖ Most HVAC systems mix both the return and outdoor air in a mixing plenum that is located before the filter bank.
 - ❖ The filtered air returns to the room as cleaner air and replaces the contaminated air that was returned to the central system



Basic HVAC System

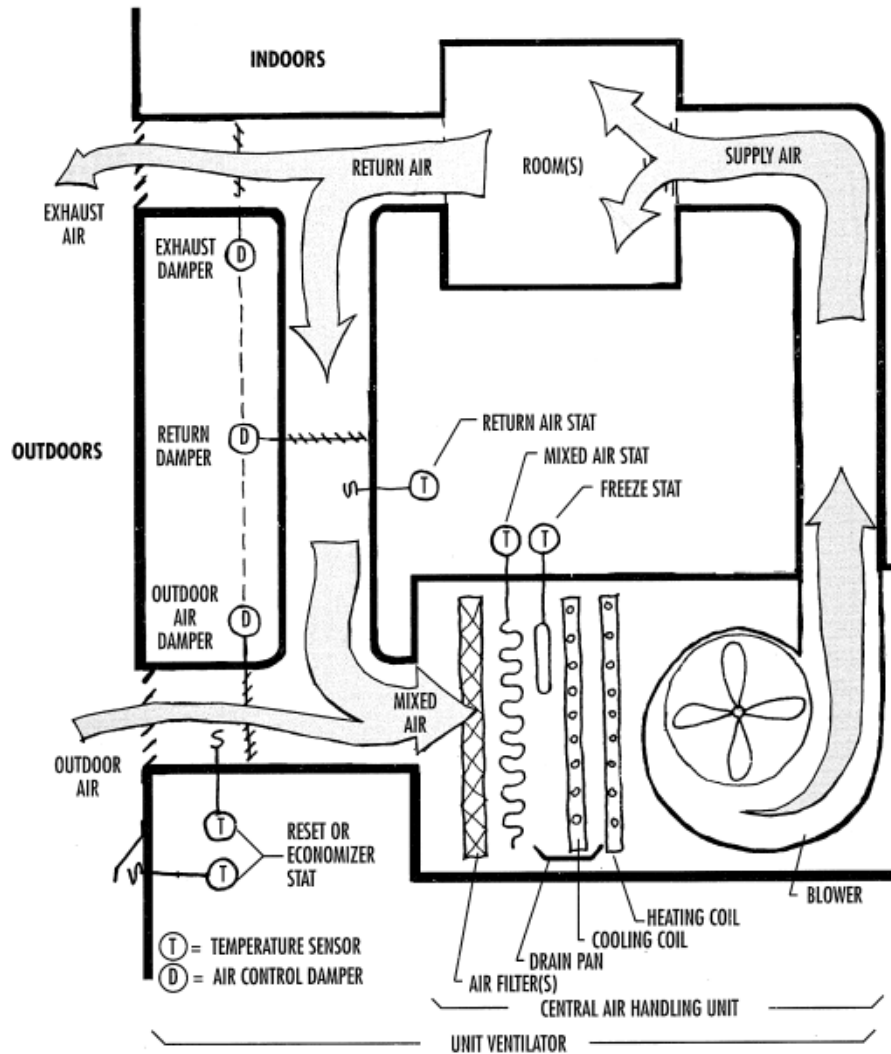


Image: EPA, [ventchklstbkgd.pdf \(epa.gov\)](https://www.epa.gov/ventchklstbkgd.pdf), accessed 10/19/2023



Air Flow Design

- ❖ Desired air flow volume is based on occupancy and activities conducted in the room
 - ASHRAE Standards set minimum air flow volume and other parameters
 - Adopted by building codes
- ❖ Air changes per hour is one benchmark used to characterize the air flow in a room
- ❖ Use measurements to determine if system operation meets as designed



Air Flow

- Measurement of air flow – either directly in the system ducts or outlet registers
 - ❖ Balometer/flow hood- measures air flow in cubic feet per minute (CFM)



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Air Changes per Hour (ACH)

❖ Air Changes per hour (ACH);

$$ACH = \frac{Q \times 60}{Room\ Volume}$$

- (Q)= Air Flow in Cubic feet per minute (CFM)
- Room Volume in Cubic feet (ft³)
- Multiple by 60 to convert minutes to hours



Example

- ❖ How many ACH with the following system set up?
 - As measured, the air flow to the room is 100 cfm
 - The volume of the room is 2000 ft³ (20 ft long x 10 ft wide x 10 ft ceiling)

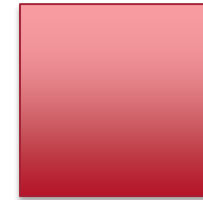
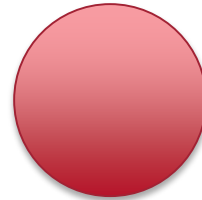
$$\frac{100 \times 60}{2000} = 3 \text{ ACH}$$



Air Ducts

❖ Common

- Round or square
- Issues:
 - Sized correctly for system
 - Proper air flow to avoid “settlement”



❖ Plenum

- Rather than ductwork, the space between the structural ceiling and the drop ceiling is used to move air
- Issues
 - Not efficient or controllable



Plenum

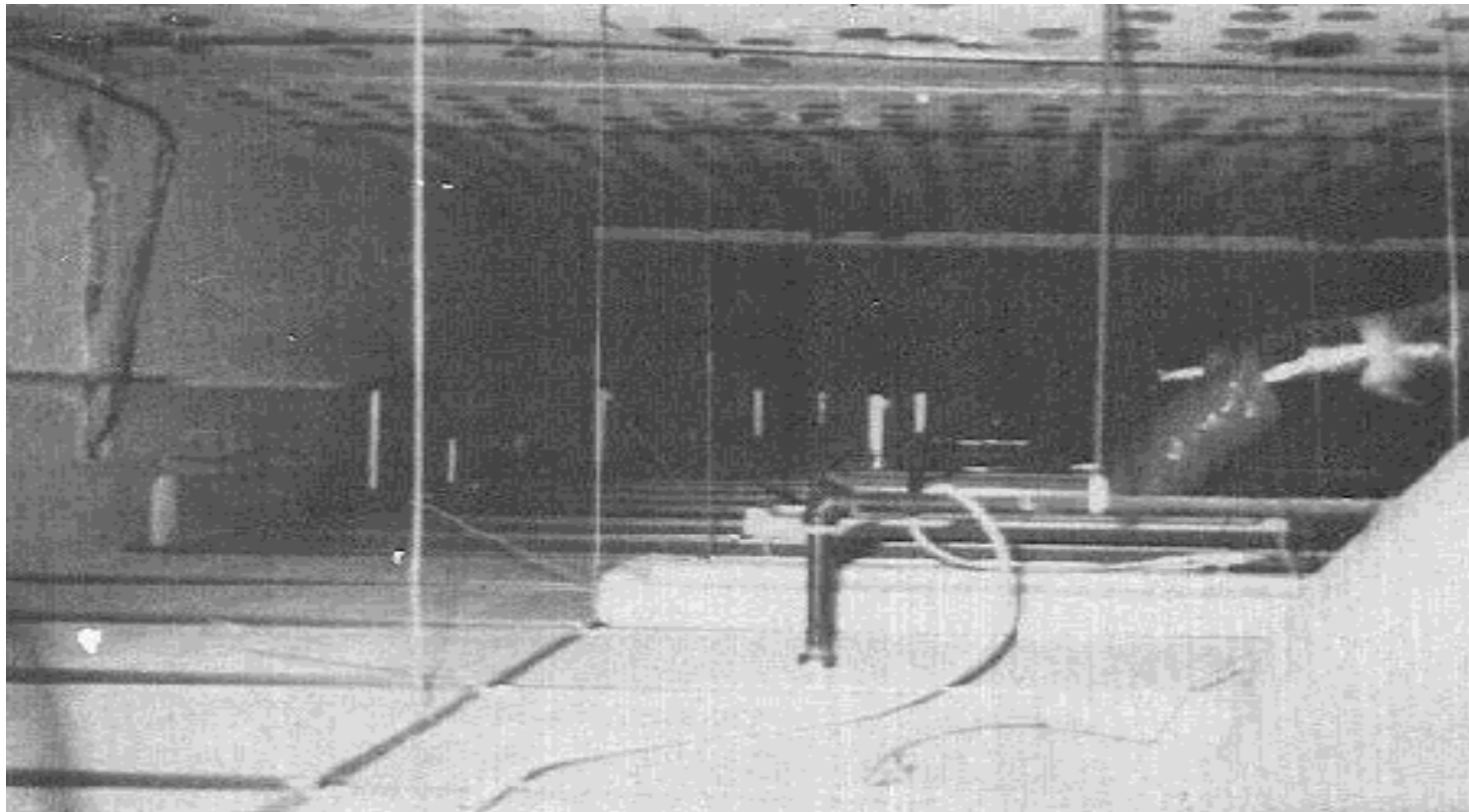


Image: Building Air Quality, "A Guide for Building Owners and Facility Managers", EPA, December 1991



Questions



Filtration

- ❖ MERV – Minimum Efficiency Reporting Value
- ❖ HEPA – High Efficiency Particulate Air Filter –recommended for healthcare –
- ❖ Ability to use a higher filter efficiency is limited by the HVAC unit



Filter Ratings

MERV

- ❖ Scale runs from 1 to 16,
 - Larger numbers representing greater capture efficiency
 - Minimum MERV 8
 - Healthcare minimum MERV 13 or higher recommended
- ❖ Performance assessed in 3 particle size ranges
 - 0.3 to 1 μm (E1)
 - 1 to 3 μm (E2)
 - 3 to 10 μm (E3)

HEPA

- ❖ Recommended for healthcare, higher than MERV 16
- ❖ 99.97% efficiency of capturing particles sized 0.3 μm and larger



MERV Ratings - Average Particle Size Efficiency (Adapted from U.S. EPA 2009, originally from ANSI/ASHRAE Standard 52.2 2007)

MERV Rating	% Removal 0.3-1 Microns	% Removal 1-3 Microns	% Removal 3-10 Microns
1-4	0%	0%	< 20%
5	0%	0%	20%-35%
8	0%	0%	> 70%
9	0%	< 50%	> 85%
12	0%	> 80%	> 90%
13	< 75%	> 90%	> 90%
16	> 95%	> 95%	> 95%
17** (HEPA/ULPA filters)	>= 99.97%	>= 99.97%	>= 99.97%
18** (HEPA/ULPA filters)	>= 99.99%	>= 99.99%	>= 99.99%
19,20** (HEPA/ULPA filters)	>= 99.999%	>= 99.999%	>= 99.999%

Table: [Air Cleaning Devices for the Home | California Air Resources Board](#), accessed 10/21/2023



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High Efficiency Isn't the Same as HEPA



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Filter Media Differences



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Pleated filters are designed to make the air flow easier through the filter



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Can't Tell Efficiency By Appearance

MERV 8

MERV 13



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Filtration and System Limitations

❖ HVAC Limitations

- Older or undersized HVAC system
- Even newer HVAC systems may not be able to handle the increased pressure required to push the air through a more efficient filter

❖ The fan that moves the air has limited capability

- Fan power,
- System components
 - Air takes the path of least resistance, filter system needs to be designed such that the air only passes through the filter and not around the filter
 - Filter rack needs to provide sealing to prevent filter bypass



Leakage Around Filter

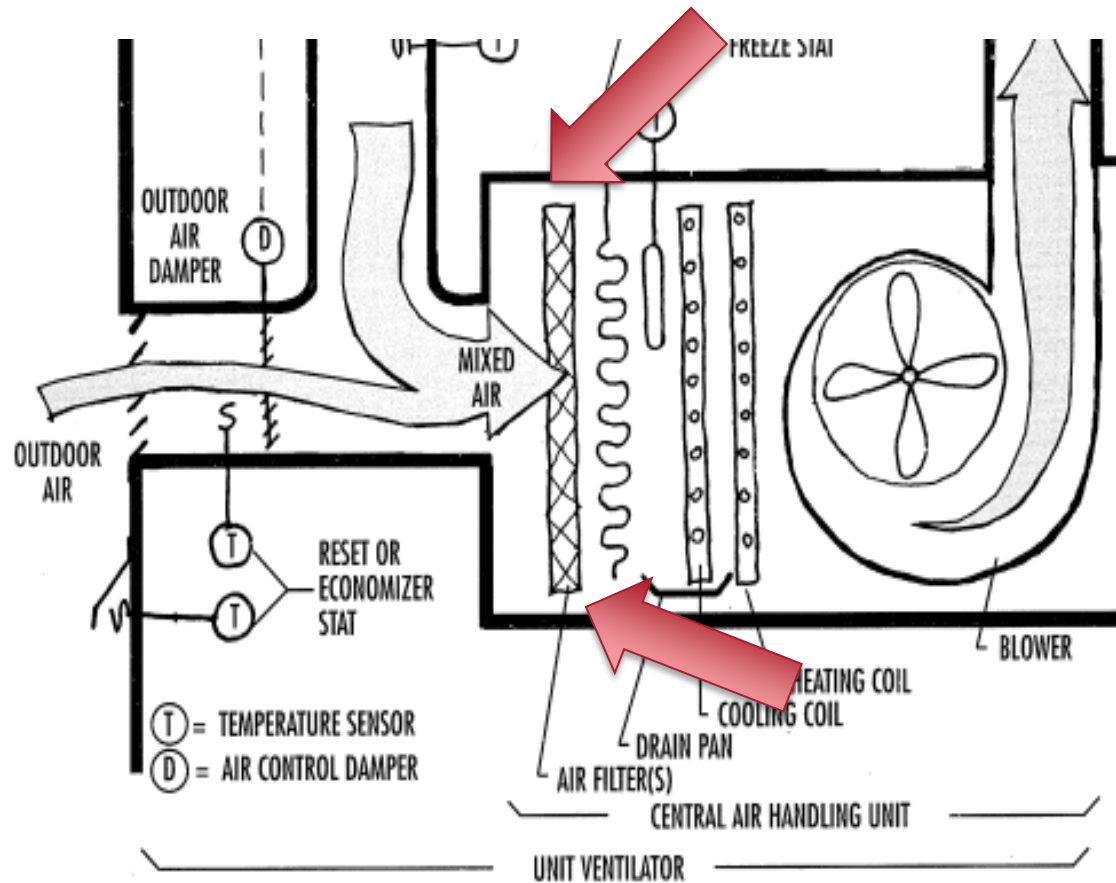


Image: EPA, [ventchk1stbkgd.pdf \(epa.gov\)](#), accessed 10/19/2023



Questions



Transmission of Infectious Aerosols

Risk depends on

- ❖ Characteristics of pathogen
- ❖ Media through which infectious agent passes from source to new host
 - Air
 - Surface
- ❖ Immune response of the new host
- ❖ Temperature and humidity of room

Transmission routes

- ❖ Inhalation of aerosols
- ❖ Spray of large droplets
- ❖ Touching contaminated surfaces



Mechanisms of Transmission

❖ Respiratory activities:

- Breathing
- Talking
- Singing
- Coughing
- Sneezing



❖ Wide range of droplets of respiratory fluid (mucus, sputum, or saliva)

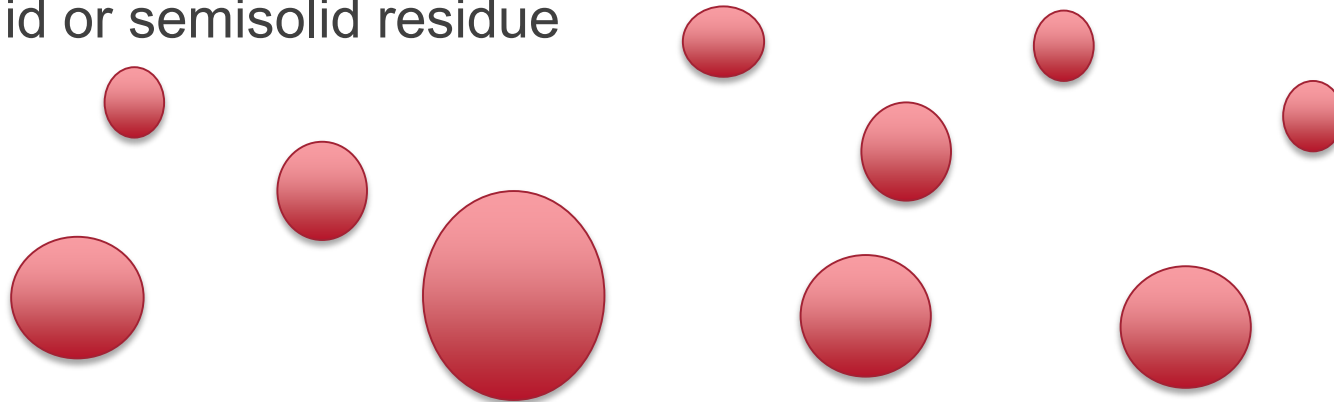
- Particle size has an influence on exposure

Image: [Catching the Flu: NIOSH Research on Airborne Influenza Transmission | Blogs | CDC](#), accessed 10/23/2023



Particle Size Dynamics

- ❖ So large, they don't remain suspended in air for more than several seconds, $>100 \mu\text{m}$
- ❖ Aerosols – ($0.01\text{-}100 \mu\text{m}$) small size that remain suspended in air for an extended time
 - Particles $5 \mu\text{m}$ or smaller are a concern for intermediate range inhalation transmission
- ❖ Smaller than aerosol, $<0.01 \mu\text{m}$, rapidly evaporate, leave behind a solid or semisolid residue





Breathing zone of occupants is where concentration and movement of aerosols can affect the risk of infection

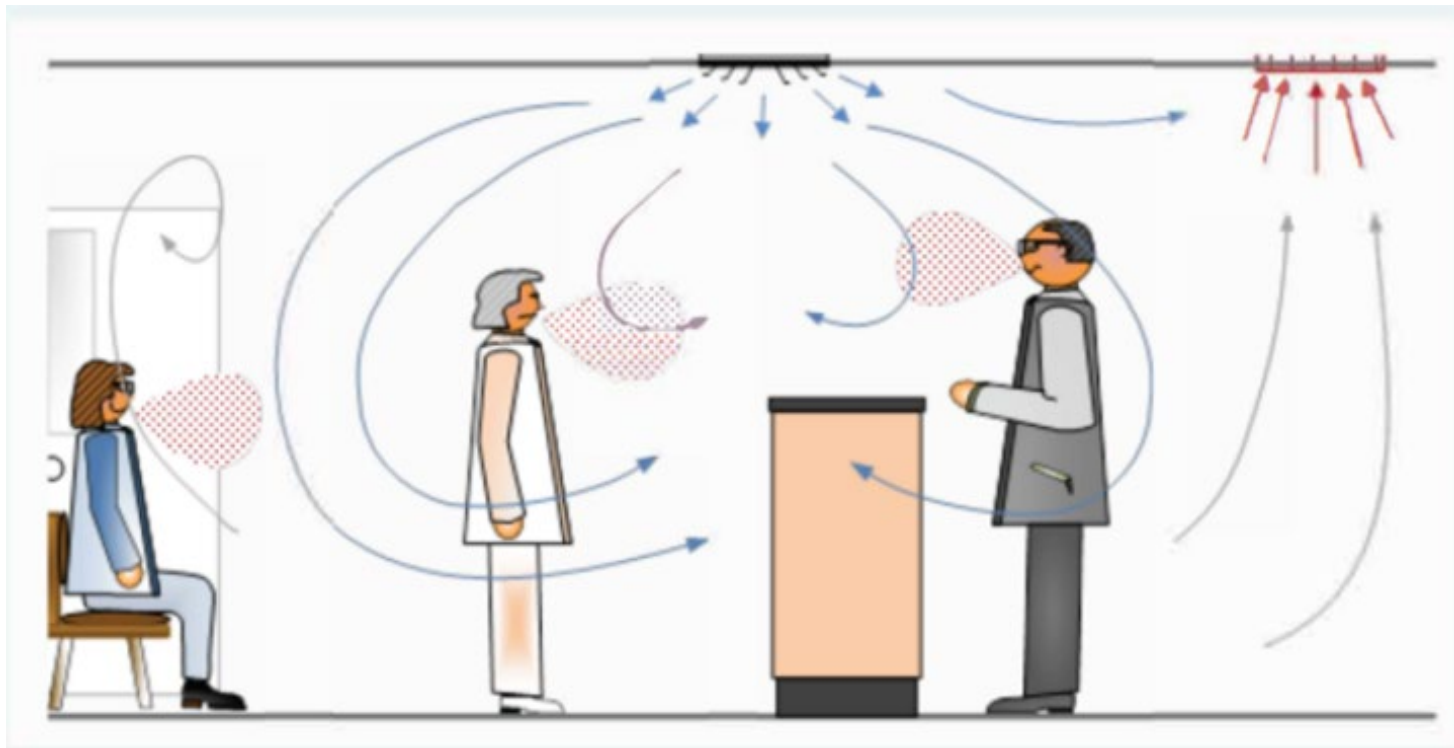


Image: [COVID-19 Fact Sheet: Airflow Patterns Matter – ACGIH](#), accessed 10/22/2023



The Role Ventilation Plays in Infection

- ❖ Only one part of a multifunction effort to reduce risk, combination of engineering and non-engineering controls
 - Ventilation can increase or decrease the risk of exposure to infectious aerosols

- ❖ Currently there is a lack of data to specify the ventilation that is needed for a particular pathogen
 - Lack of data related to infectious source strength and dose response to calculate the dilution level required to reduce exposure

- ❖ Still a factor that can be utilized in most situations or at minimum evaluated to ensure that it is not increasing risk



Factors That Influence Air Flow Patterns

- ❖ Supply diffusers
 - Number
 - Location
 - Type
 - Airflow rate
- ❖ Room air change rates
- ❖ Supply air temperature
- ❖ Return/exhaust grilles
 - Number
 - Size
 - Location
- ❖ Location and strength of other heat sources
- ❖ Arrangement of furniture and other obstructions in relation to air flow patterns
- ❖ In-room air cleaners
 - Location
 - Type
 - Capacity
- ❖ The relative positions of contaminant sources in the space



Air Flow Patterns

Desired

- ❖ Well mixed:
 - Good sweep and removal,
 - “Clean” air is brought in to sweep the room
 - Return air removes “used” air

- ❖ Fresh air intake reduces contaminants

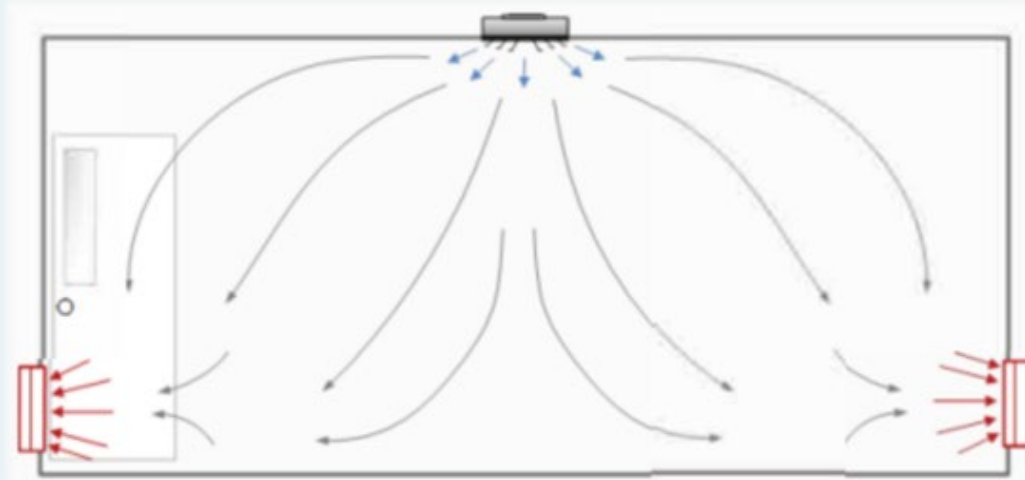
Undesired

- ❖ Short circuiting
- ❖ Exhaust only
- ❖ Supply only
- ❖ No exhaust
- ❖ No supply



Well Mixed

PROPER SUPPLY AND EXHAUST CAN SIGNIFICANTLY REDUCE THE RISK OF EXPOSURE



Consider optimizing the type and location of supply and exhaust to enhance airflow, mixing, dilution and removal of contaminants.

Image: [COVID-19 Fact Sheet: Airflow Patterns Matter – ACGIH](#), accessed 10/22/2023



Short Circuiting

- ❖ Short-circuiting -when the supply air flows to exhaust registers before entering the breathing zone.
 - Factors that can contribute to short-circuiting
 - To avoid short-circuiting, the supply air must be delivered at a temperature and velocity that results in mixing throughout the space.

- ❖ Commonly found when spaces are divided into multiple rooms
 - Offices
 - Doctor's offices

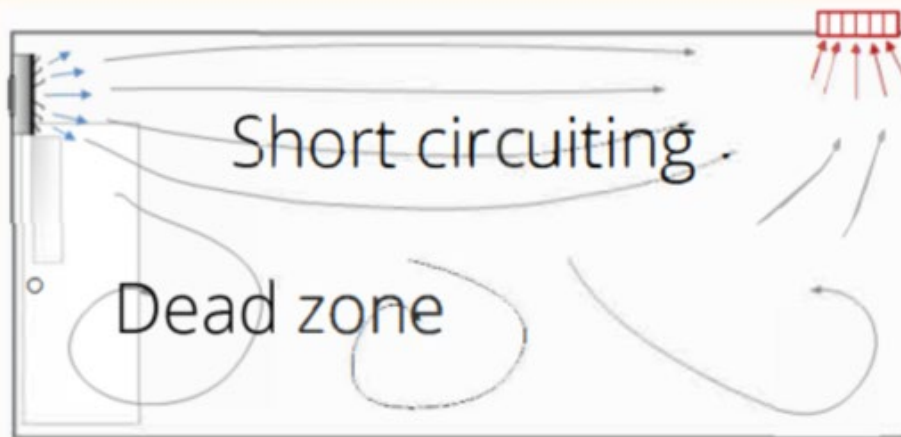


Short Circuiting





AIRFLOW PATTERNS ARE IMPORTANT



Placement and design of inlets and outlets can cause poor mixing, dead zones, short circuiting and concentration build-up.

Image: [COVID-19 Fact Sheet: Airflow Patterns Matter – ACGIH](#), accessed 10/22/2023



Obstructions to Air Flow Patterns





Questions



Air Disinfection

Ultraviolet Germicidal Irradiation (UVGI)

- ❖ Ultraviolet Germicidal Irradiation, (UVGI), also known as Germicidal Ultraviolet disinfection (GUV) – uses ultraviolet radiant energy to inactivate bacteria, mold spores, fungi or viruses
 - Wavelengths in the Ultraviolet (UV) spectral band
 - UV-C band wavelengths - 200 to 290 nanometers (nm) range most effective

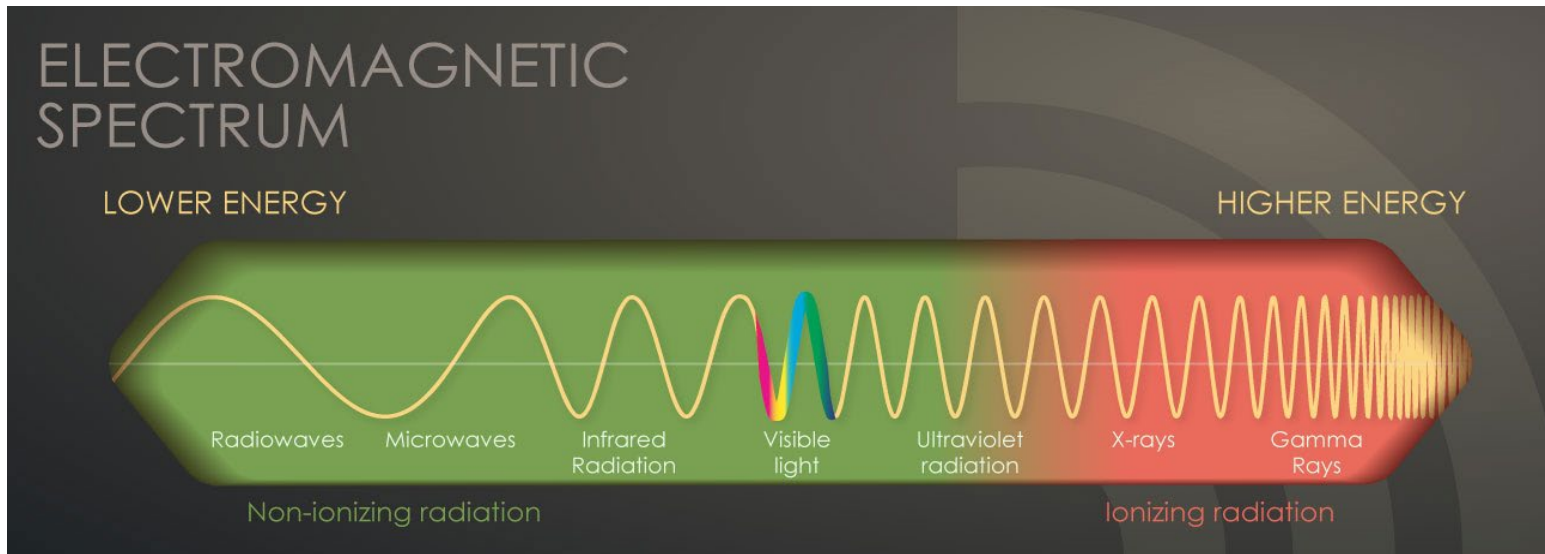


Image: [Radiation Studies - CDC: The Electromagnetic Spectrum](#), accessed 10/23/2023



Applications of Ultraviolet Germicidal Irradiation (UVGI)

- ❖ Tuberculosis (TB) 1950's
- ❖ Room or Air duct/coil applications
- ❖ UV-C robots, used to disinfect surfaces after they have been cleaned
 - Long, vertical mercury lamps, or
 - Pulsed xenon lamps
- ❖ New technology, LEDs and excimer lamps have potential to allow both air and surface disinfection simultaneously



Room UVGI Considerations

- ❖ Likelihood of sick people being present, e.g. healthcare waiting rooms
- ❖ Crowded spaces
- ❖ Spaces with insufficient or no mechanical HVAC system or natural ventilation cannot be maintained
- ❖ Professionally designed and installed
- ❖ Safety/operation training for employees
 - Eye and skin damage



Room UVGI Limitations

- ❖ UVGI, not a standalone solution
 - Still air, contact time in order to achieve disinfection
 - Ceiling height, minimum of 8.5 feet recommended

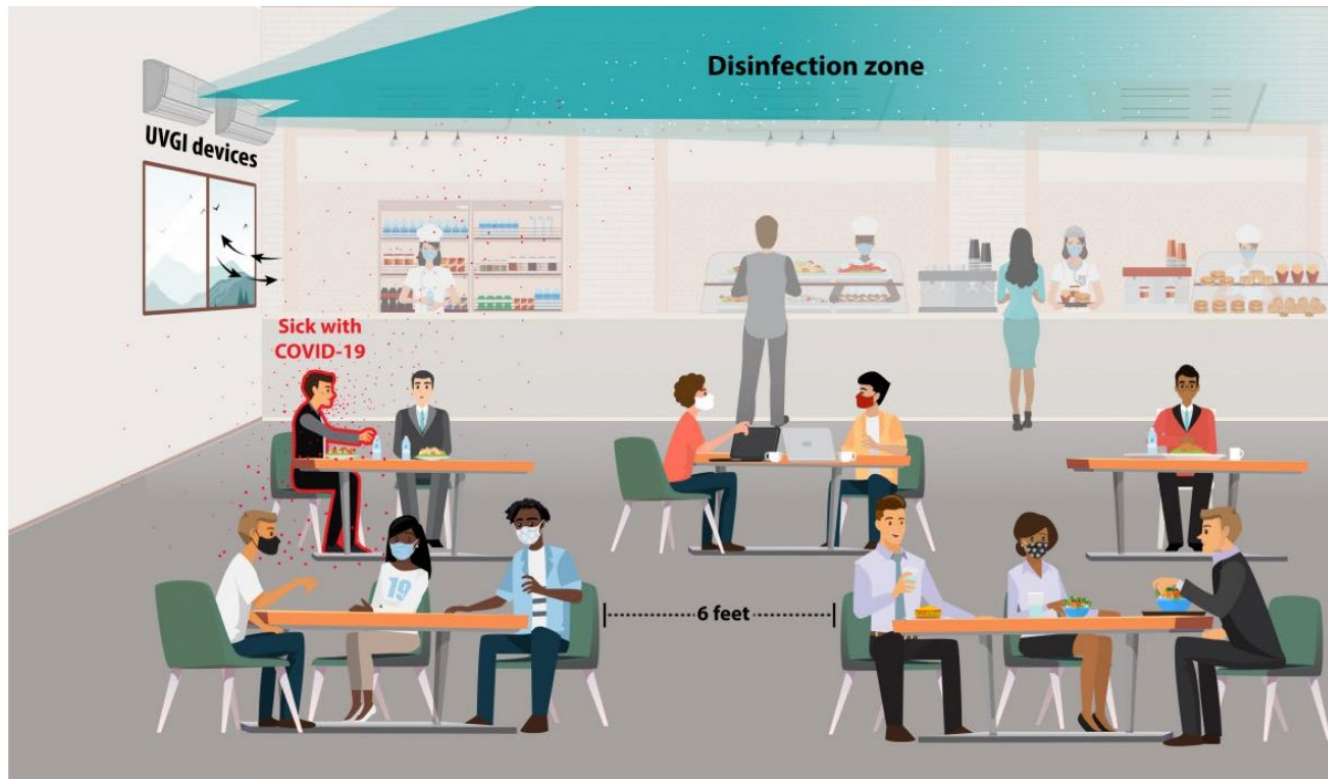


Image: [Upper-Room Ultraviolet Germicidal Irradiation \(UVGI\) | CDC](#), accessed 10/19/2023



Air Duct UVGI Considerations

- ❖ Disinfects recirculated air, but doesn't disinfect room air
 - Requires increased dose of UV due to air movement through the duct work
- ❖ General recommendations
 - 500 fpm or slower moving air stream
 - Minimum irradiance zone, 2 feet
 - Minimum UV exposure time of 0.25 seconds
 - Coupled with mechanical filtration



Image, Epidemic Task Force, Filtration & Disinfection, [ashrae-filtration_disinfection-c19-guidance.pdf](#), accessed 10/19/2023



Other Options to UVGI Electronic Air Cleaners

- ❖ Electronic Air Cleaners – produce various reactive species such as ions, hydroxyl radicals, peroxides and other species

- ❖ Ozone a product of concern
 - Ozone based air cleaners should not be used
 - Nor cleaning technologies that may produce ozone as a by product

- ❖ UL 2998 Standard, requires that air cleaners produce less than 5 parts per billion of ozone

- ❖ Can also produce various chemical contaminants and aerosols
 - Reactive species (ions, hydrogen peroxides, etc.) can also be harmful
 - More data is needed to determine effectiveness and risks of this type of air cleaner



Questions



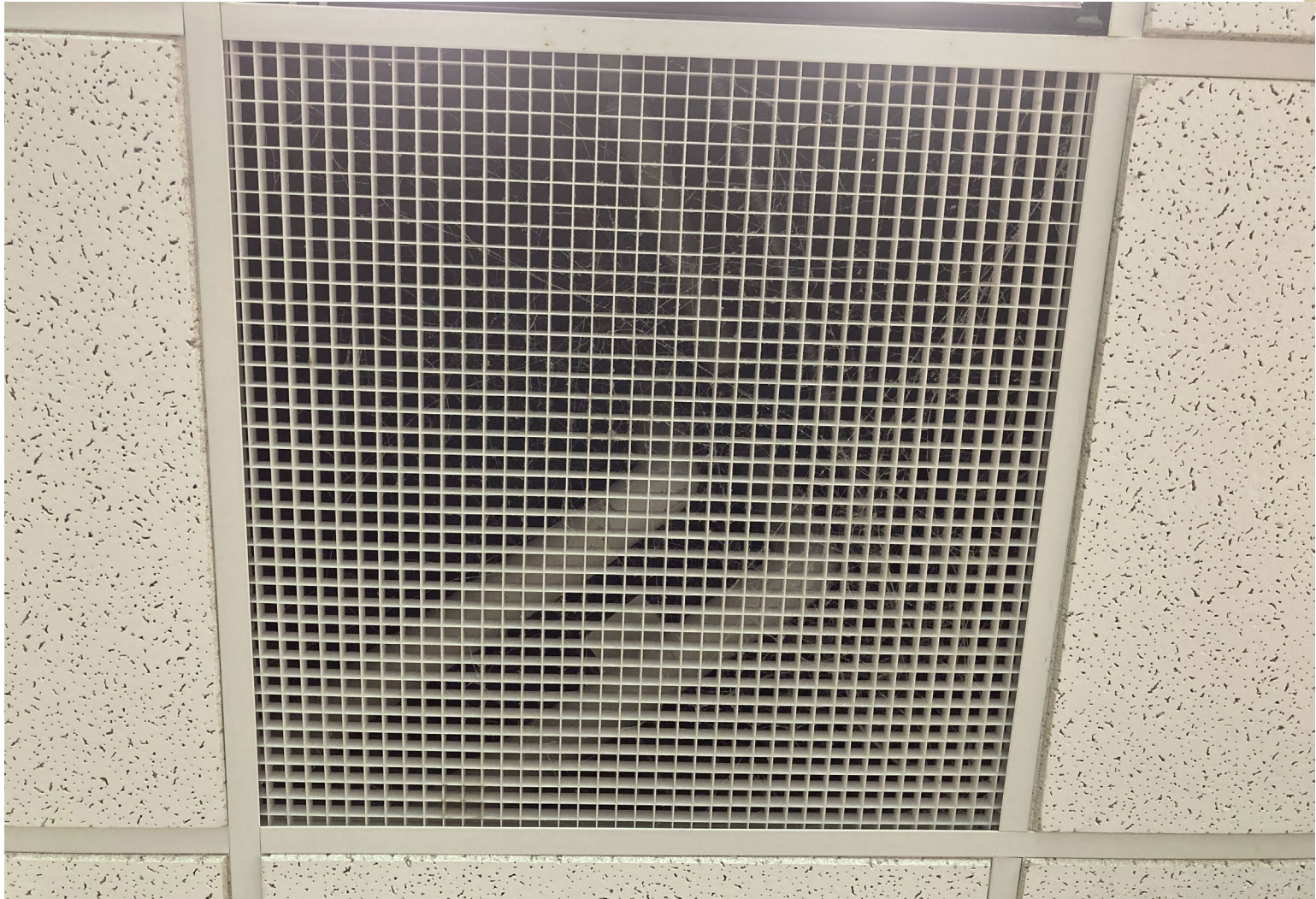
Basic System Maintenance

- ❖ Filter changes - adequate supply on hand
- ❖ Routine maintenance – inspections of drain pans, coils, duct work, manufacturer's recommendations for routine maintenance
- ❖ Routine maintenance of system should also include wiping vents



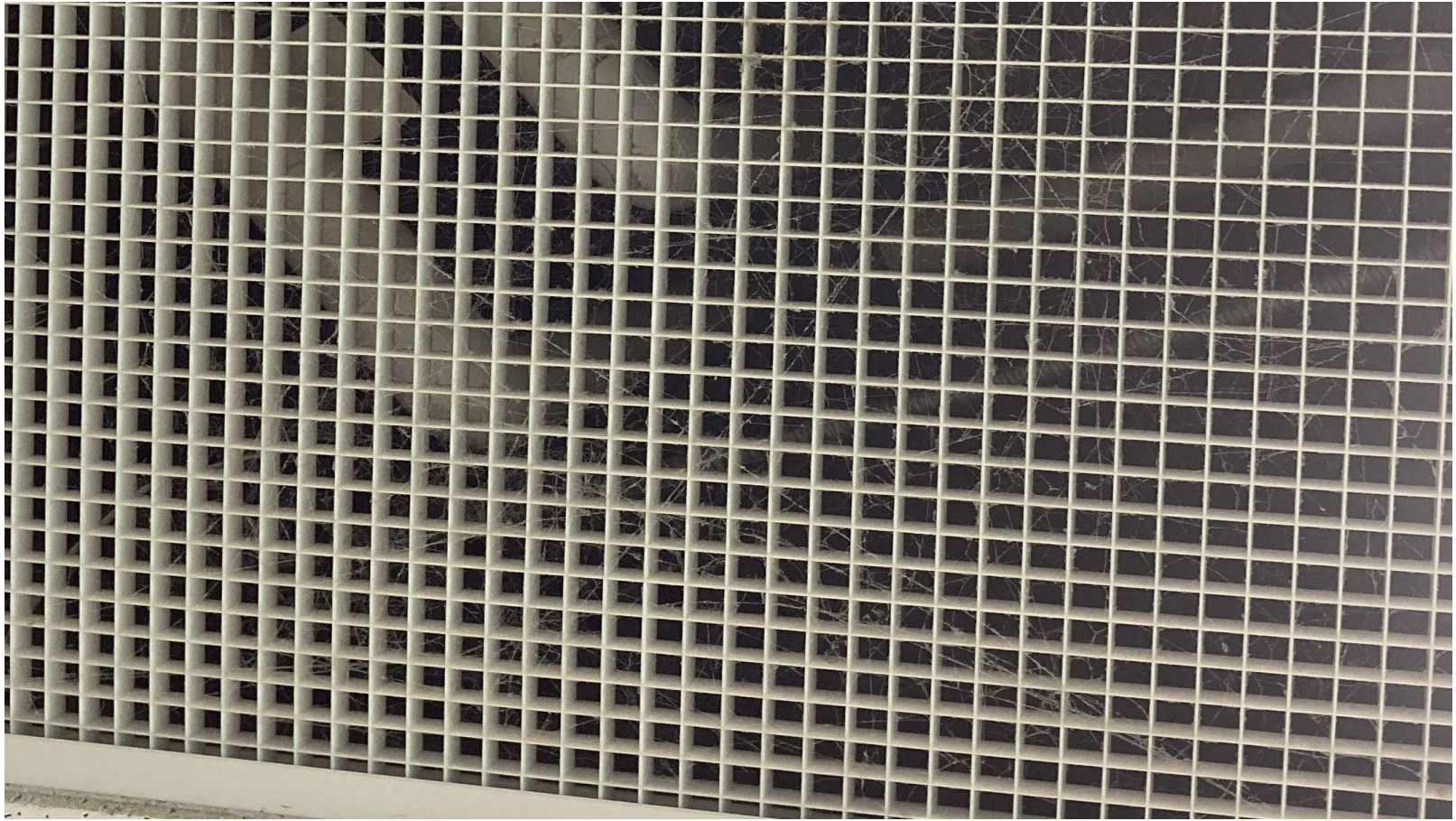
Vent Cleaning







Close Up of Previous Image





Periodic Maintenance

- ❖ Checking and balancing system



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Other Considerations

- ❖ Personnel protection for maintenance activities:
 - Safety glasses
 - Gloves
 - Respiratory protection

- ❖ Some HVAC units may be considered a confined space

- ❖ Proper disposal of used filters
 - Filter contains the materials that were filtered out of the air



Building Renovations

❖ Protection of HVAC system

- Shut down system
- Tape off vents, windows and doors
- Exhaust to the outside to create a negative pressure

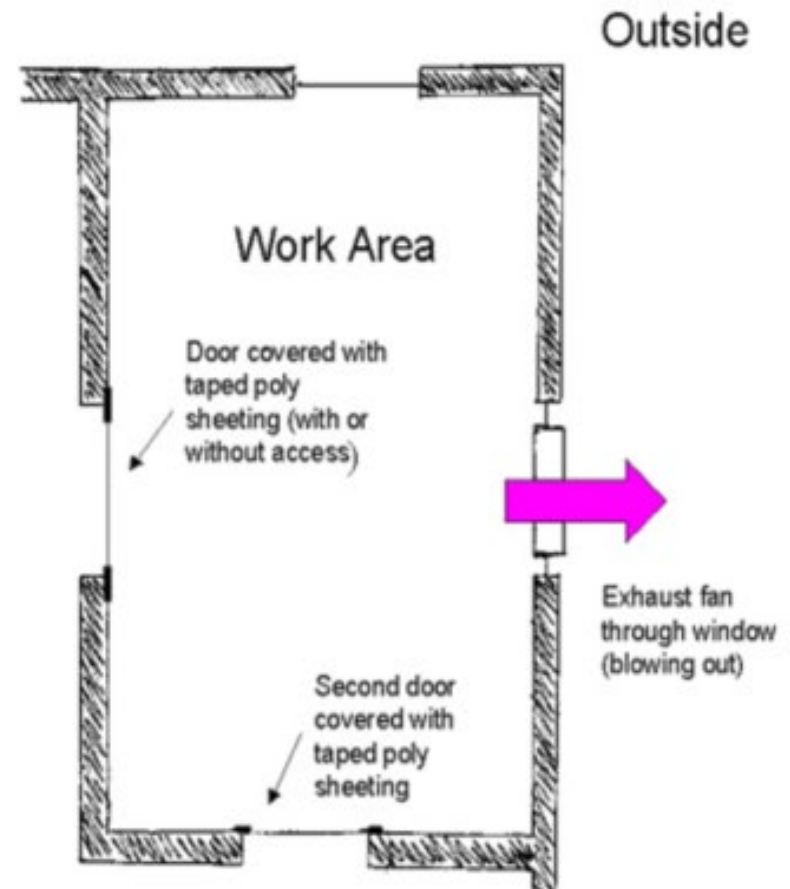


Image: [Best Practices for Indoor Air Quality when Remodeling Your Home | US EPA](#), accessed 10/23/2023



Alternative Ventilation During System Shutdowns

- ❖ Portable HEPA filter units (negative air units) used in asbestos and lead removal activities, hospital grade available



- ❖ Portable Air Cleaners

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Considerations for Portable Air Cleaners

- ❖ CADR, Clean Air Delivery Rate, laboratory tested at highest setting
- ❖ Room size – usually best for single room use
 - Large space, high ceilings, odd room configuration
- ❖ Supply and exhaust locations of unit will have an impact on existing room air flow patterns
- ❖ Avoid additional functions other than air filtration
- ❖ Number and location of units
- ❖ Cost of unit maintenance and replacement filters



AHAM

- ❖ The Association of Home Appliance Manufacturers (AHAM) – trade association representing manufacturers of major, portable and floor care appliances and suppliers to the industry.
 - Develops technical and performance standards
 - Administers third party appliance verification programs



繁體中文



 Consumers

 Manufacturers

ABOUT AIR CLEANERS

WHY BUY AN AIR CLEANER

AIR FILTRATION STANDARDS

FIND A CERTIFIED ROOM AIR CLEANER

[Image: Air Filtration Standards - AHAM Verifide](#), accessed 10/22/2023



Portable Air Cleaner Ratings

❖ Clean Air Delivery Rate (CADR)

- Measure of the appliance's ability to reduce particles sized 0.10 to 11 μm
 - Smoke
 - Dust
 - Pollen

❖ Tested at highest setting, so the noise of the unit(s) may become an issue

❖ Rating only applicable to portable air cleaners, e.g. test methods do not apply to whole house cleaners



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**ANSI/AHAM AC-1:
Method for Measuring the Performance of Portable Household
Electric Room Air Cleaners**

Understanding its Scope and the Related AHAM Industry Certification Program

(08/29/2014)

[Image: Air Filtration Standards - AHAM Verifide](#), accessed 10/22/2023



CADR

- ❖ AHAM recommends that the CADR of the cleaner should be equal to at least $\frac{2}{3}$ of the room's area
 - Assumes an 8 foot ceiling
 - A room 10 feet by 12 feet has an area of 120 square feet (ft²)
 - CADR of at least 80

- ❖ For wildfire smoke, AHAM recommends a CADR equal to the size of the room in square feet






Certification Label Example

AHAM[®] Independently Tested.
VERIFIDE Consumer Trusted.

AIR CLEANER SUGGESTED CLOSED ROOM SIZE
310 SQUARE FEET

**CLEAN AIR DELIVERY RATE
& ENERGY TESTED**
The higher the CADR numbers, the faster the units clean the air

TOBACCO SMOKE	DUST	POLLEN
 200	 190	 180

Honeywell – HPA204
Kaz USA, Inc.
400 Donald Lynch Blvd. Suite 300
Marlborough, MA 01752 USA

Portable air cleaners are most effective in rooms where all doors and windows are closed. Suggested room size is based on 4.8 Air Changes per hour.

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Placement of Portable Air Cleaners

- ❖ Depending on the room size and/or the configuration, you may need more than one unit
 - Large room
 - Ceilings higher than 8 feet
 - Odd room configuration
- ❖ The goal is to get as much of the room air as possible to flow through the unit
- ❖ DO NOT place air cleaners
 - Next to corners,
 - Doorways,
 - Curtains,
 - Furniture
 - Walls, or
 - Windows
- ❖ Preferably they should be about 3 feet away from obstructions



Placement of Portable Air Cleaners, cont.

- ❖ Room supply and exhaust locations, impact on air flow patterns
- ❖ Keep obstructions from the unit's intake and exhaust, and not pointed directly at occupants
- ❖ If feasible, air cleaners should remain on and maximized in the space 2 hours before and after occupancy



Questions



Summary

- ❖ Ventilation systems are designed for a specific use and occupancy
- ❖ Often changes are made to a room's layout and/or use, these changes effect the ventilation patterns
- ❖ Ventilation systems need to be:
 - Checked after room or purpose modifications and periodically
 - Routinely maintained
 - Vents/grill need to be routinely cleaned
- ❖ While a higher filter rating is more effective at removing particles, the ventilation system can only handle the designed filter rating
- ❖ Room air flow patterns can increase or decrease the risk of aerosol infections
- ❖ The use of portable air cleaning units requires knowledge of the room's configuration and air flow patterns



Contact Information

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Onsite Safety & Health Consultation Program



Wisconsin State
Laboratory of Hygiene

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Thank you

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Acronyms & Common Terms

Acronyms

- ❖ ASHRAE – American Society of Heating, Refrigeration, and Air Conditioning Engineers – global society whose ventilation publications are adopted/referenced by building codes and health and safety professionals
- ❖ HEPA – High Efficiency Particulate Air Filter –recommended for healthcare –99.97% efficiency of 0.3 μm
- ❖ HVAC – Heating, Ventilation and Air Conditioning
- ❖ MERV – Minimum Efficiency Reporting Value

Common Terms

- ❖ ACH – Air Changes per Hour
- ❖ Aerosol - (0.01-100 μm) an assemblage of small particles, solid or liquid suspended in air
- ❖ Air Changes per Hour – delivering or exhausting an amount of air that is equal to a room's volume over a 60 minute period
- ❖ Dampers – Controls that vary airflow through an air outlet, inlet or duct
- ❖ Diffuser-distributes air to promote air circulation in the occupied space
- ❖ Grill – in conjunction with diffusers, returns air to the system



Common Terms Cont.

- ❖ Make-up Air –(Fresh Air; Replacement Air, Compensating Air) Air brought into a building from the outdoors through the ventilation system that has not been previously circulated through the system
- ❖ Micrometer, μm – A unit of length equal to 10^{-4} centimeters, approximately 1/25,000 inches
- ❖ Mixing Plenum – A chamber within an HVAC system where outdoor air is mixed with returned air. The mixed air, after cleaning and conditioning, becomes the supply air for the building
- ❖ Supply Air Diffusers – Devices that deliver the supply air to the occupied zone and provide a desired distribution pattern. Diffusers can be circular, square, rectangular, linear slots, louvered, fixed, adjustable or a combination
- ❖ Return Air Grilles – Return air grilles may be a louvered or perforated, covering for openings located in the sidewall, ceiling or floor of a zone through which the return air enters. The return air grilles may be directly connected to an open return air plenum or to a ducted return air system.



Resources

❖ CDC

- [Infection Control Guidelines](#)
- [Ventilation in Buildings | CDC](#)
- [Air | Background | Environmental Guidelines | Guidelines Library | Infection Control | CDC](#), HVAC Systems in Health-Care Facilities
- [Air | Appendix | Environmental Guidelines | Guidelines Library | Infection Control | CDC](#) – Appendix B, Airborne Contaminate Removal Tables
- [Upper-Room Ultraviolet Germicidal Irradiation \(UVGI\) | CDC](#)



Resources

❖ NIH

- [Practical Considerations for Using Portable Air Cleaners to prevent Transmission of Infectious Aerosols: Background \(nih.gov\)](#)
- [Selection and Use of Portable Air Cleaners to Protect Workers from Exposure to SARS-CoV-2 \(nih.gov\)](#)

❖ ASHRAE

- Infectious Aerosols, October 13, 2022, [PD_-Infectious-Aerosols-2022_edited-January-2023.pdf \(ashrae.org\)](#), accessed 10-19-2023
- Epidemic Task Force, Filtration & Disinfection, [ashrae-filtration_disinfection-c19-guidance.pdf](#), accessed 10/19/2023



Resources

- ❖ Association of Home Appliance Manufacturers
 - [Scope of Air Cleaner Certification 2014 \(00030526\).DOCX \(ahamverifide.org\)](#)
 - [AHAM Frequently Asked Questions about Testing of Portable Air Cleaners](#)
- ❖ Illuminating Engineering Society, GUV information
 - [IES-CR-2-20-V1-6d.pdf](#)
- ❖ EPA
 - [Guide to Air Cleaners in the Home | US EPA](#)
 - [Indoor Air Quality \(IAQ\) | US EPA](#)