ASHRAE's New Standard 241
Airborne Infection Protection for Buildings

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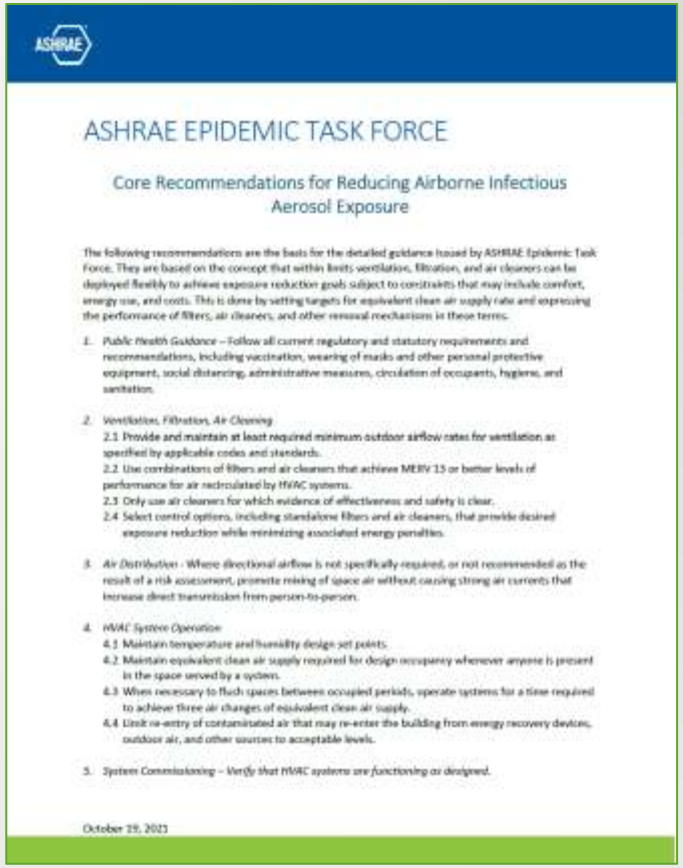
ASHRAE

Maine Indoor Air Quality Council

IAQ & ENERGY 2023 CONFERENCE

2 Why develop a standard for airborne infection risk mitigation?

- Airborne transmission of infections can be important
- Potential harm from airborne infections is great
- Indoor environment affects risk
- Current IAQ standards don't airborne transmission
- Complete/codify ASHRAE Epidemic Task Force guidance
- The White House asked for it…



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ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

1. *Public Health Guidance* – Follow all current regulatory and statutory requirements and recommendations, including vaccination, wearing of masks and other personal protective equipment, social distancing, administrative measures, circulation of occupants, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

4. *HVAC System Operation*
   4.1 Maintain temperature and humidity design set points.
   4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

October 19, 2021

Time line for development of Standard 241-2023

Oct 21

White House Covid Response
Team recognizes importance of buildings, begins interacting with ASHRAE and others

Mar 22

White House
"Clean Air in Buildings Challenge"

National Model IAQ Code Discussions
2nd half of 2022

Sep 22

Johns Hopkins Workshop
"A National Strategy for Improving Indoor Air Quality"

Oct 22

White House
"Summit on Indoor Air Quality"

Nov 22

White House
Asks ASHRAE to develop a "national pathogen control" standard ASAP, preferably before COVID restrictions on May 11

Dec 22

Dec 6 ASHRAE Commitment
ASHRAE Board commits to developing a consensus, code-language, non-ANSI standard in 6 months

Call for Members

Jan 23

ASHRAE Standards Committee Approvals
Roster, Title, Purpose & Scope of Standard 241P approved at winter meeting

Feb 23

Development Begins
1st full project committee meeting on February 28 (day 0)

Mar 23

May 23

Public Review draft approved by project committee on May 11 (73 days)

Jun 23

Project committee recommends publication
June 15 (108 days)

APPROVED
ASHRAE approves Standard 241 for Publication at annual meeting on June 24 (116 days)

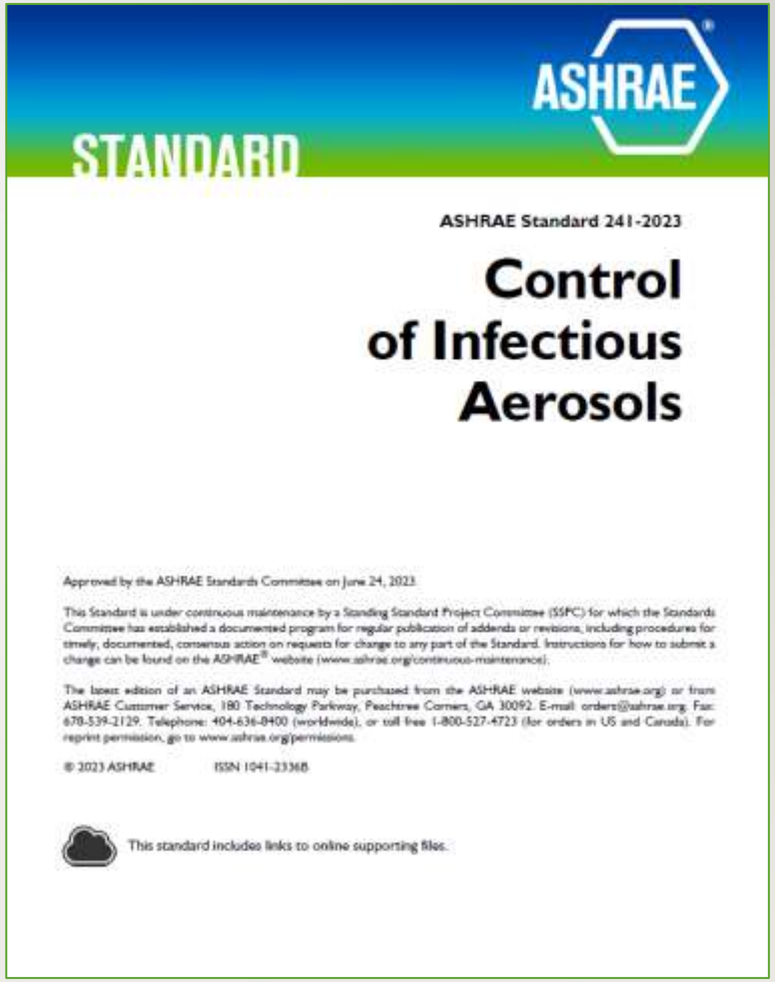
Dr. Ashish Jha – former Coordinator, White House COVID-19 Response Team

"(T)his effort to try to improve indoor air quality, reduce the burden of respiratory pathogens – yes, it's been something we have been talking about at the White House – yes, a lot of experts have been talking about it. Talking is good. Talking is important, but what ASHRAE did over the last six months in building out the standards, the 241 standards, that just got approved on Saturday, fundamentally changes the game.

It is one of the most important public health interventions I have seen in years, if not decades."

Purpose and scope

- Purpose
  - Establish minimum requirements for control of infectious aerosols to reduce risk of disease transmission in occupiable space of new and existing buildings and major renovations (non-residential, residential, health care)
  - Outdoor air systems, air cleaning systems
    - Design
    - Installation
    - Commissioning
    - Operation
    - Maintenance
  - Specify equivalent clean airflow to be provided in infection risk management mode
- Scope
  - Does NOT establish overall requirements for acceptable indoor air quality
  - Addresses long range transmission, i.e., outside close proximity to an infector



STANDARD

ASHRAE

ASHRAE Standard 241-2023

Control of Infectious Aerosols

Approved by the ASHRAE Standards Committee on June 24, 2023

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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This standard includes links to online supporting files.

Main topics

- Definitions
- Prerequisites
- Equivalent clean airflow for infection risk mitigation
- Air distribution and natural ventilation
- Air cleaning
- Assessment, planning , implementation
- Operations and maintenance
- Additional requirements for dwelling units
- Normative and informative appendices

Prerequisites

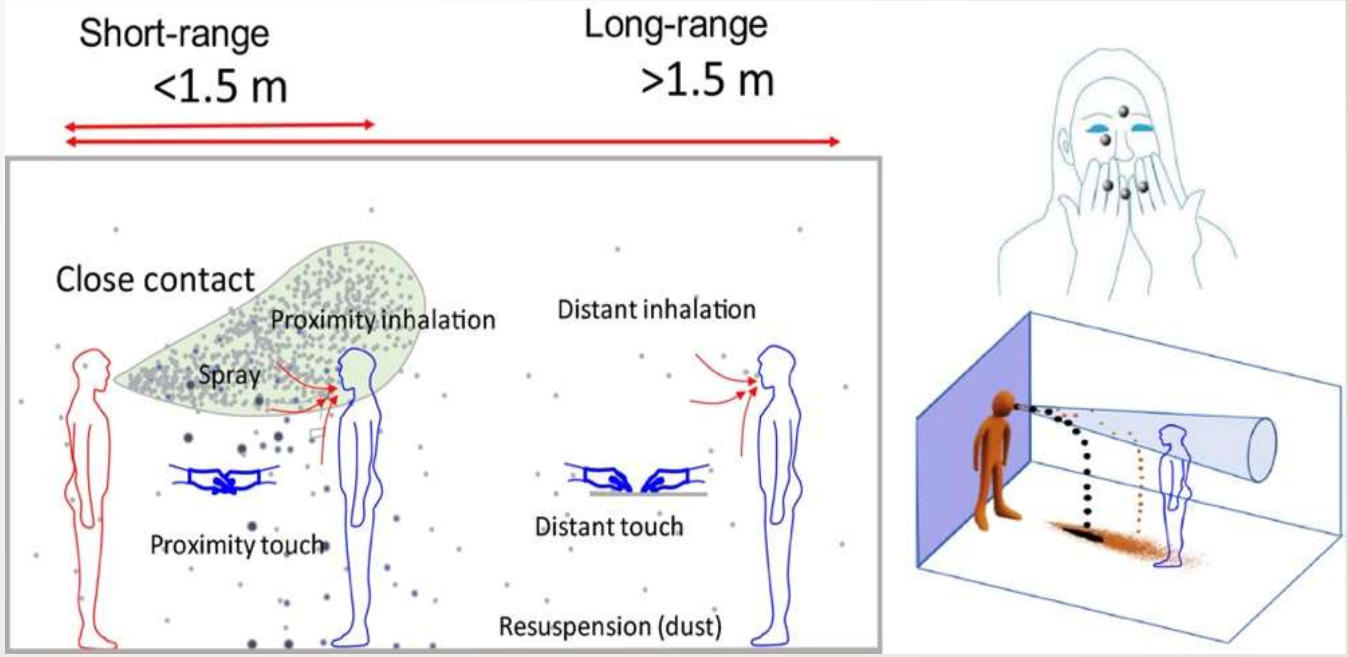
- Standard 241 only addresses infection risk
- Must comply with version of ASHRAE 62.1, 62.2, 170 or other standard approved by the authority having jurisdiction based on occupancy and date of construction/major renovation
- Prerequisite standards set minimum requirements of outdoor air and filtration for normal operation
- IAQP may be the compliance path for 62.1

Key definitions

- Long-range transmission
- Infectious aerosol
- Air cleaning
- Infection Risk Management Mode (IRMM)
- Building Readiness Plan (BRP)
- Equivalent Clean Airflow (ECA)

Long-range transmission

- Transmission by exposure to infectious aerosol not in close proximity to an infector
- Basis for risk assessment
- Focus on long-range does not mean there is no effect on short-range



Li, Y. 2020. *Indoor Air.* DOI: 10.1111/ina.12786

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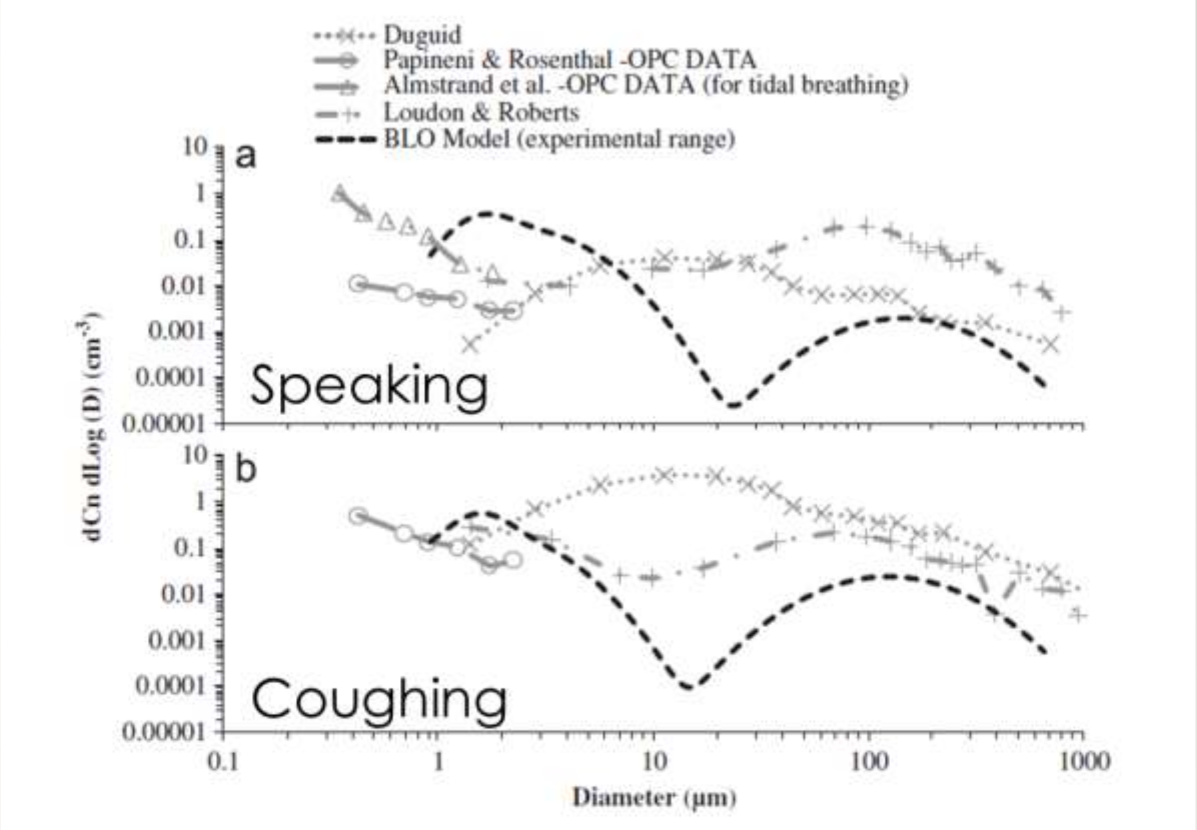
Infectious aerosol

- Airborne particles containing active pathogens capable of causing infection
- Size, emission rate determined by respiratory activity, not pathogen size



Johnson, et al. 2011. Modality of human expired aerosol size distributions. Journal of Aerosol Science 42:839-851.

Air Cleaning

- Reducing infectious aerosol concentration through capture and removal or inactivation
- Air cleaning technologies
  - Mechanical filters (including electret media)
  - Germicidal ultraviolet light
  - Reactive species – ionizers, photocatalytic oxidation, other oxidants
- *Mention of specific technologies in the standard is not endorsement!*

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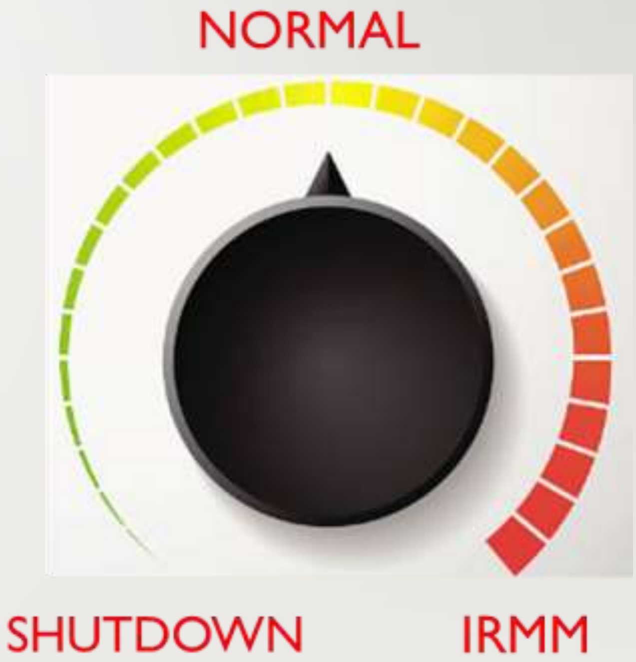
Infection Risk Management Mode (IRMM)

- The mode of operation in which measures to reduce infectious aerosol exposure documented in a building readiness plan are active
- Decision on IRMM Enable / Disable
  - Public health official
  - Owner
  - Occupant
- Why not all the time?
  - Potential Energy use and cost increase
  - Infection risk and consequences of infection vary over a wide range
- An example of resilience applied to IAQ



Building Readiness Plan (BRP)

- *A plan that documents the engineering and non-engineering controls that facility systems will use for the facility to achieve its goals*
- Summarizes results of assessment and planning exercises and documents measures to be implemented in IRMM
- Adopted with modifications from ASHRAE Epidemic Task Force guidance

Equivalent Clean Airflow (ECA)

- *The flow rate of pathogen-free air that, if distributed uniformly within the breathing zone, would have the same effect on infectious aerosol concentration as the sum of actual outdoor airflow, filtered airflow, and inactivation of infectious aerosols*
- Concept on which the entire standard depends
  - Determine ECA for infection risk mitigation (ECAi)
  - Determine total flow rate for spaces, systems (V_{ECAi})
  - Figure out how to achieve it during IRMM

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Equivalent Clean Airflow for an Air Filter

V_{RC} – Actual recirculated flow through air cleaner

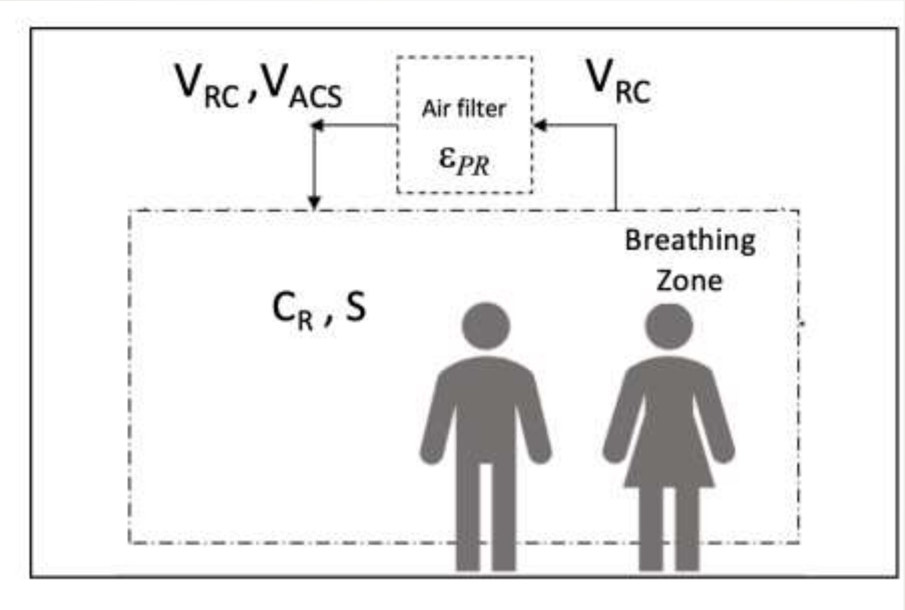
V_{ACS} – Equivalent clean airflow of air cleaner

ε_{PR} - Filter single-pass efficiency (%)

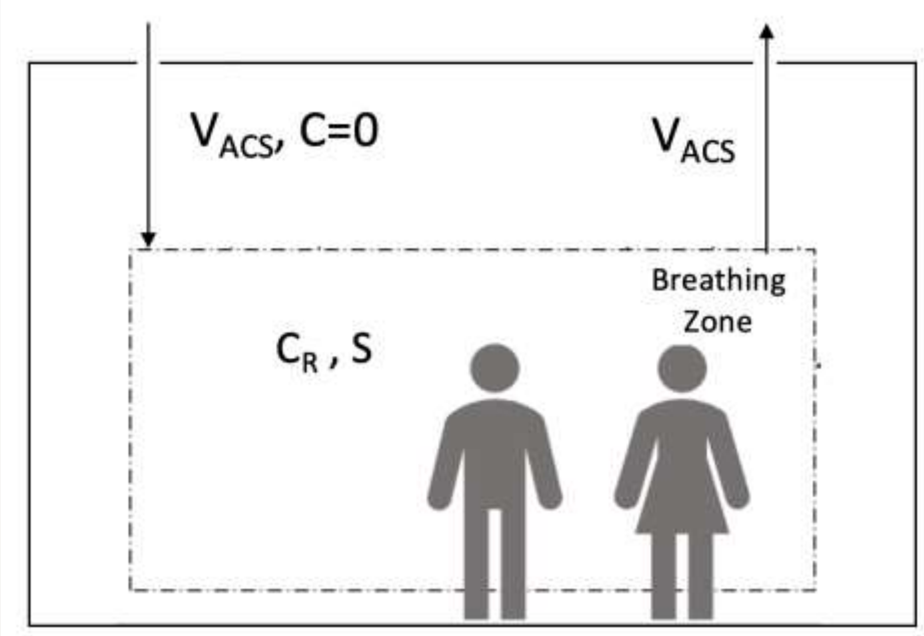
C – Infectious aerosol concentration

C_R – Concentration in space

Actual air cleaning system



Equivalent dilution process



Can show (with a little math…) that $V_{ACS} = \frac{\varepsilon_{PR}}{100} \times V_{RC}$

ECA requirements are based on risk assessment

- Many decisions to make
  - Absolute or relative risk
  - Acceptable risk level
  - Infector number and emission rate, infectious dose
  - Exposure time
  - Susceptible number and activity level
  - Removal/inactivation mechanisms
    - Engineering controls
    - Personal protective equipment
    - Natural loss – decay, deposition
- Probabilistic approach is needed
  - Most factors are distributed (not single valued)
  - Some factors vary over orders of magnitude
- What is the most appropriate unit?
  - ECA per person?
  - ECA per infector?
  - ACH of ECA?
  - ???

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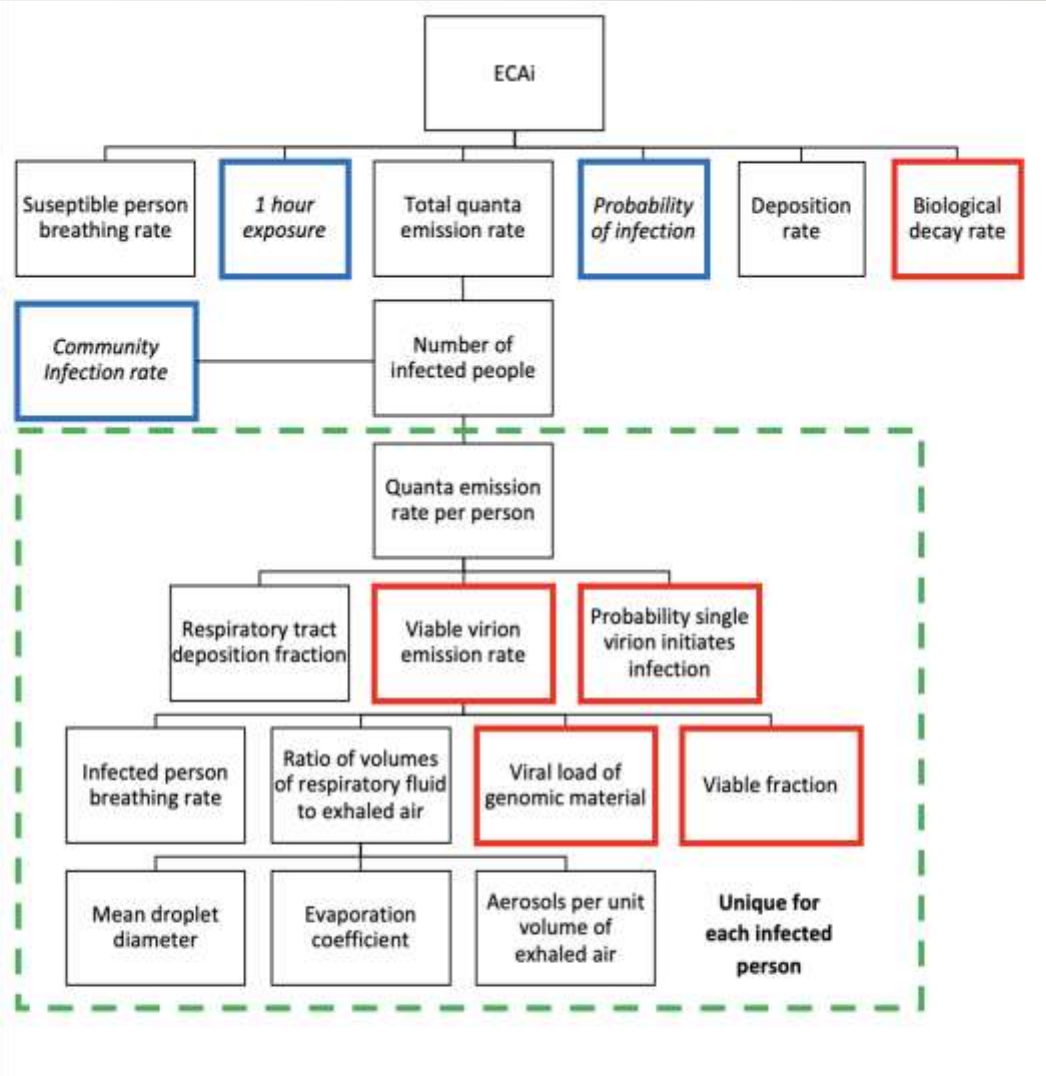
Risk assumptions in Standard 241

- Wells-Riley model
  - Some variables are **deterministic**. Other variables are probabilistic using distributed variables.
  - Some variables are **based on SARS-COV-2**.
  - Variables inside the **green box** represent variables that are **unique for each infected person**.
- Low individual risk per hour
- Equal risk for all space types



18 The required ECA depends on space type, number of people and activity

- Occupancy categories
  - Correctional facilities
  - Commercial/retail
  - Educational facilities
  - Industrial
  - Health-care
  - Public assembly/sports & entertainment
  - Residential
- 25 space types – office, classroom, food and beverage, etc.
- ECAi range 20-90 cfm/pers (10-40 L/s-pers) values doubled if there is loud vocalization

$$V_{ECAi} = ECAi \times P_{Z,IRMM}$$

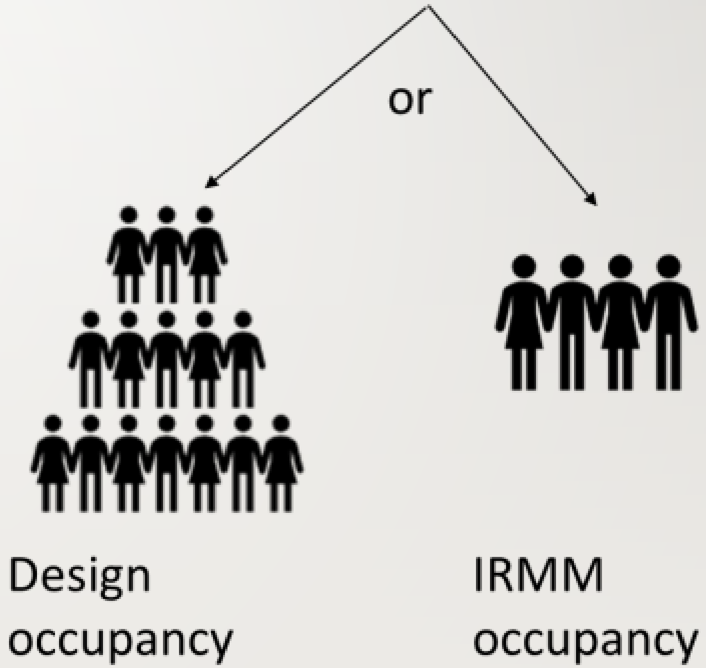


Table 5-1 – Minimum Equivalent Clean Airflow per Person in Breathing Zone in IRMM

Occupancy Category	ECAi cfm/person	ECAi L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10

Occupancy Category	ECAi cfm/person	ECAi L/s/person
Health Care		
Exam room	40	20
Group treatment area	70	35
Patient room	70	35
Resident room	50	25
Waiting room	90	45
Public Assembly/Sports and Entertainment		
Auditorium	50	25
Place of religious worship	50	25
Museum	60	30
Convention	60	30
Spectator area	50	25
Lobbies	50	25
Residential		
Common space	50	25
Dwelling unit	30	15

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Comparing standard 62.1 outdoor air, CDC recommendations, and ECAi

- ECAi rates are much higher than 62.1 OA rates…but closer after effect of filters is added
- Constant risk ECAi values give very different ACH values for different space types
- CDC recommends 5 eACH all the time
- ECAi has units of flow rate per person because personal risk of infection scales with ECA per person

ANSI/ASHRAE Standard 62.1 VRP inputs

	R_P [cfm/pers]	R_A [cfm/ft^2]	Occupant Density [#/1000 ft^2]
Office	5	0.06	5
Classroom	10	0.12	35
Restaurant	7.5	0.18	70

	ASHRAE 62.1 Default [cfm/pers]	ASHRAE 241 ECAi [cfm/pers]	ASHRAE 241 ACH with 8′ ceiling
Office	17	30	1.1
Classroom	13	40	10.5
Restaurant	10	60	31.5

Wells-Riley model of infection risk

$$P = \frac{N_I}{N_S} = 1 - \exp\left(-\frac{Iqpt}{Q}\right)$$

$$P \approx \frac{Iqpt}{Q} \; \textit{for small} \; \frac{Iqpt}{Q}$$

$$P \approx \frac{(N_S R_C)qpt}{Q} \propto \frac{1}{Q/N_S}$$

P = probability of a susceptible person becoming infected [ ]

N_I = number of new infections

N_S = number of susceptible persons

R_C = community infection rate [ ]

I = number of infectors

q = quanta (infectious dose) emission rate [1/hr]

p = pulmonary ventilation rate per susceptible [m^3/h]

t = exposure time [hr]

Q = equivalent clean airflow [m^3/h]

- If rate of infection in the population is considered, personal risk depends on the equivalent clean air flow rate per person
- Air change rate is not directly relevant!

Meeting the equivalent clean air target

- V_{ECAi} requirement can be met by
  - Outdoor airflow – mechanical/natural
  - ECA from multizone air cleaning systems
  - ECA from in-room air cleaning systems
- Approach allows maximum flexibility to user
- Limitations on compliance
  - Must have prerequisite minimum outdoor air, VRP or IAQP
  - For ECA credit, mechanical filters must be MERV-A 11 or higher (MERV 11 acceptable until 1/1/2025) or equivalent

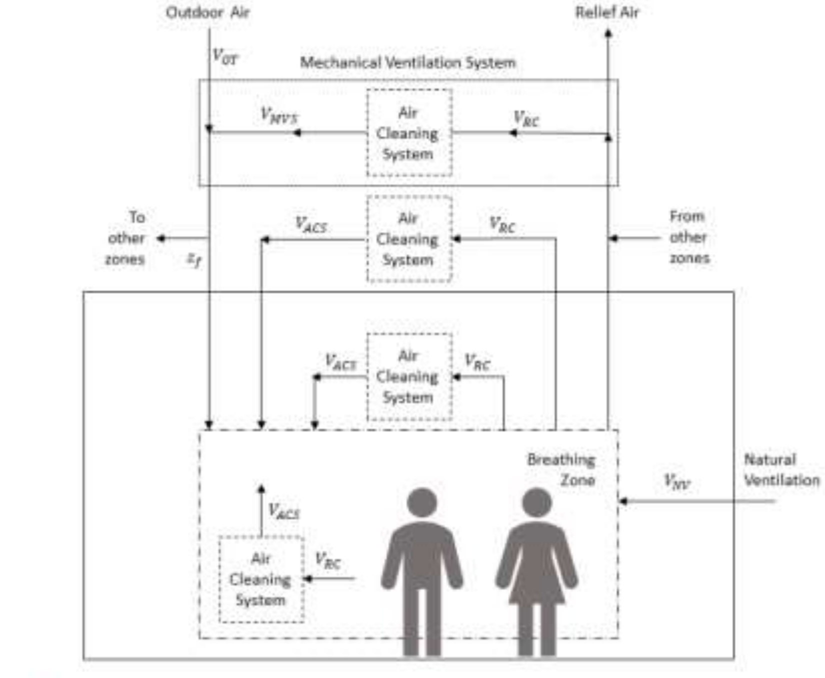


Figure 6-1 Sources of outdoor and clean air (for V_{RC}, see Section 7).

Energy, carbon, and cost

Increased outdoor air can be more energy intensive than upgrading particulate filtration from lower efficiency (MERV 7) to higher efficiency (MERV 13).

TABLE 2 Cost per cfm of outdoor air and particulate filtration (MERV 7 and MERV 13) for 15 climate zones.

CLIMATE ZONE	$/cfm OF OUTDOOR AIR	$/cfm FILTRATION STRATEGY		BLENDED UTILITY RATE $/kWh
		MERV 7	MERV 13	
1A	1.66	0.03	0.11	0.15
2A	1.55	0.03	0.12	0.14
2B	0.81	0.03	0.12	0.15
3A	0.65	0.03	0.12	0.14
3B	0.79	0.03	0.12	0.14
3C	0.16	0.06	0.25	0.28
4A	1.82	0.06	0.22	0.24
4B	0.84	0.03	0.14	0.15
4C	0.63	0.03	0.11	0.12
5A	3.25	0.06	0.26	0.28
5B	0.74	0.03	0.12	0.14
6A	2.63	0.03	0.16	0.16
6B	1.21	0.03	0.09	0.10
7A	2.98	0.03	0.16	0.16
8A	4.16	0.03	0.16	0.16

Zaatari, M, A. Goel, and J. Maser. 2023. ASHRAE J. 65(9):18-24.

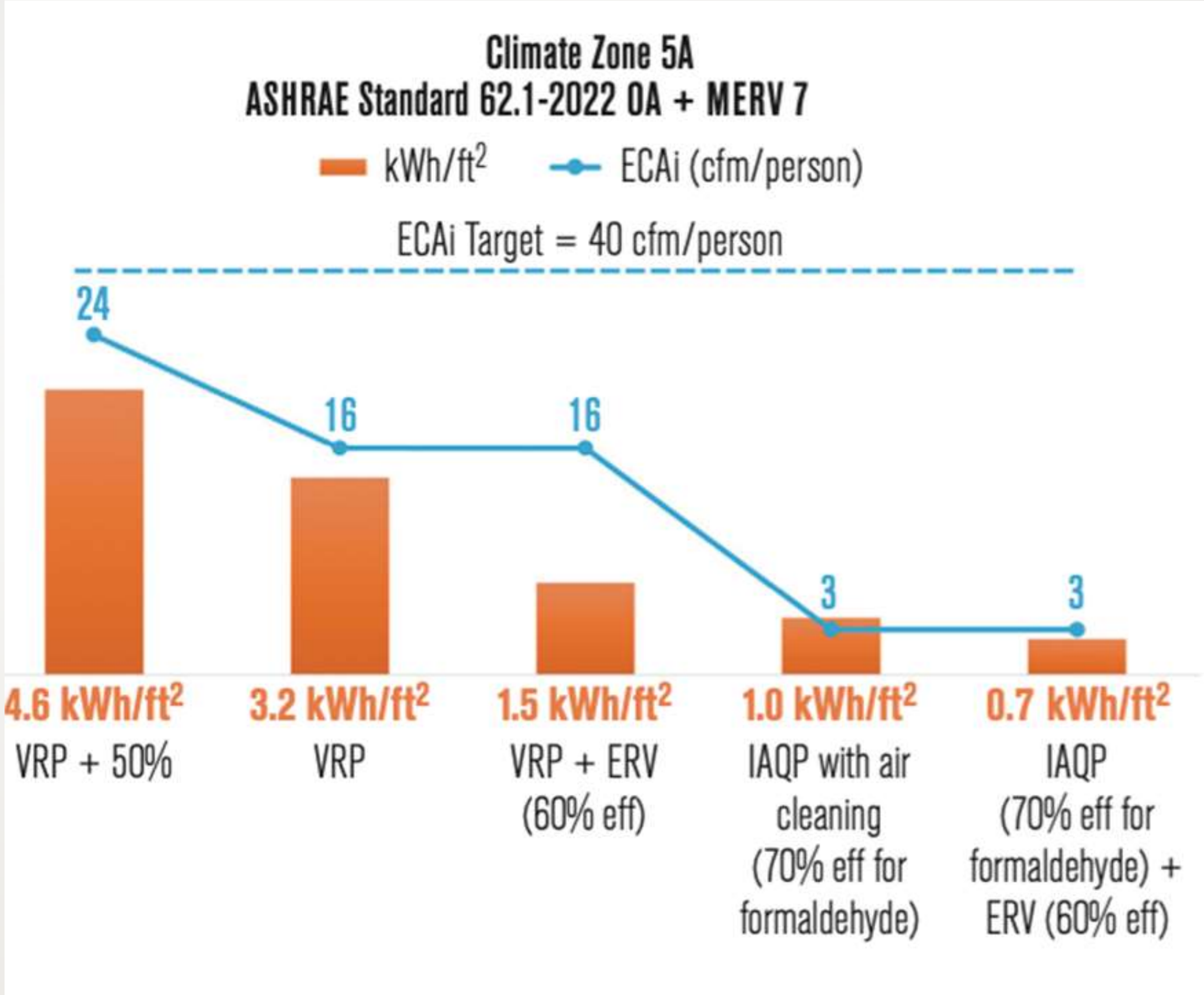
Example: Primary School
73,959 ft^2 (6871 m^2)
1,478 People

With MERV 7 filter, does not comply

VRP = outdoor air per ASHRAE 62.1-2022 prescriptive Ventilation Rate Procedure

IAQP = Outdoor air per ASHRAE Standard 62.1-2022 performance-based approach with sorbent filters capable of removing formaldehyde (HCHO) at efficiency of 70%

ERV = Energy Recovery Ventilation



Zaatari, M, A. Goel, and J. Maser. 2023. ASHRAE J. 65(9):18-24.

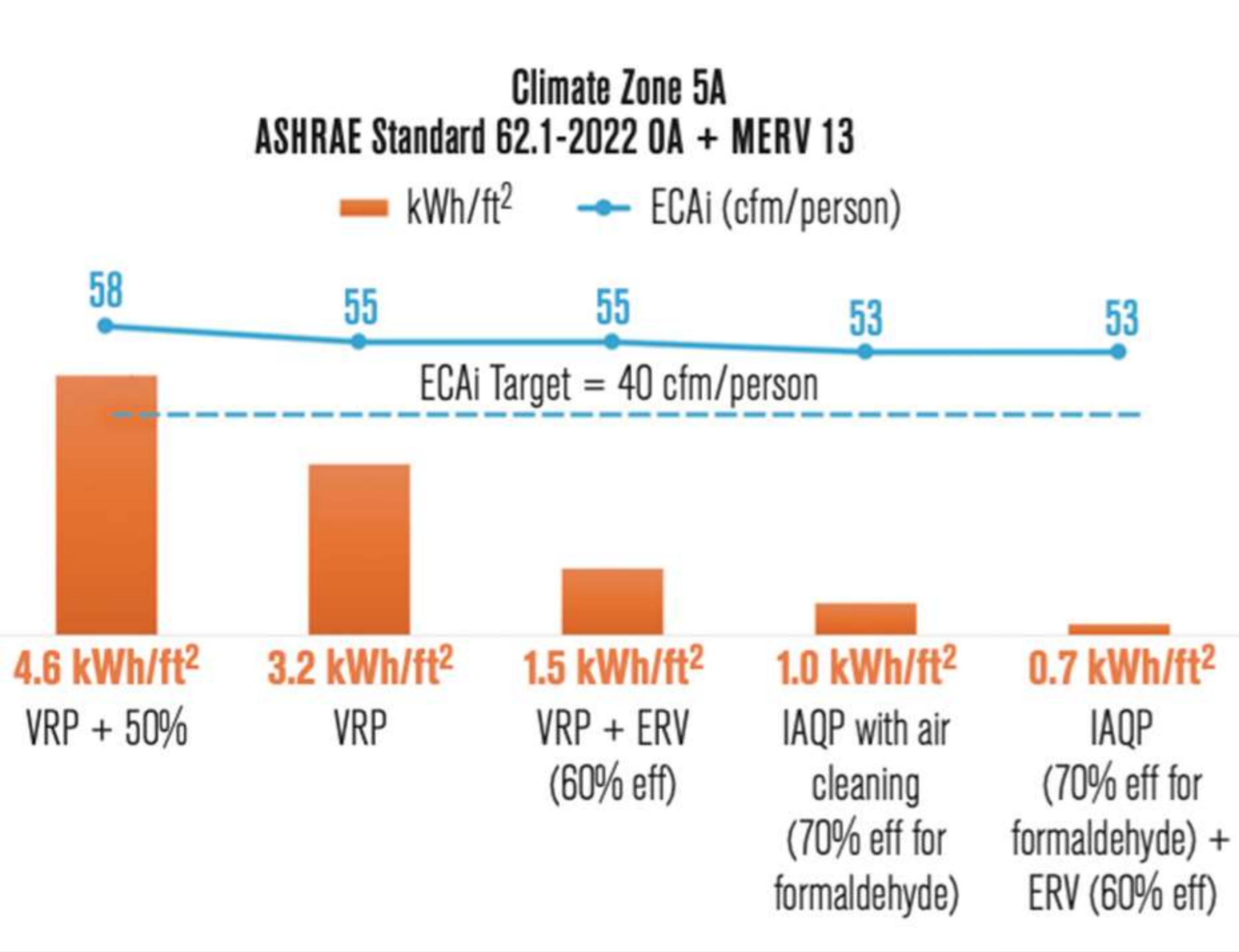
Example: Primary School 73,959 ft^2 (6871 m^2) 1,478 People

With MERV 13 filter, exceeds ECAi requirement

VRP = outdoor air per ASHRAE 62.1-2022 prescriptive Ventilation Rate Procedure

IAQP = Outdoor air per ASHRAE Standard 62.1-2022 performance-based approach with sorbent filters capable of removing formaldehyde (HCHO) at efficiency of 70%

ERV = Energy Recovery Ventilation



Zaatari, M, A. Goel, and J. Maser. 2023. ASHRAE J. 65(9):18-24.

Air distribution and natural ventilation

- Important but difficult topic, mostly for future development
- Classifies air cleaning system location (floor, wall, ceiling) and air discharge (up, down, horizontal, none) and limits some combinations based on room air distribution type (e.g., downflow air cleaner discharge with upflow air distribution)
- Mainly references ASHRAE Standard 62.1 for natural and mixed-mode ventilation requirements
- Does not yet address ventilation/contaminant removal effectiveness

Air cleaning system effectiveness and safety

- Lack of information and standards related to air cleaning systems was a major problem during the Covid pandemic
- Effectiveness – ability to remove or inactivate infectious aerosols
- Safety – adverse effects direct exposure (UV-C, oxidants), secondary contaminants (particles, ozone)
- Standard 241 establishes minimum requirements for effectiveness and safety testing

Air cleaning system testing

- Standard 241 does not recommend or rank technologies
- Standard 241 establishes a level playing field to enable use of effective, safe technologies
- Existing methods of test are referenced when available
  - ASHRAE 52.2
  - ASHRAE 185.1
  - AHAM AC-1
  - AHAM AC-5
  - ISO 16890
- Normative Appendix A provides procedures when a standard is not available

Air cleaning systems are classified generically

- In-Duct Air Cleaning Systems that Clean Air in the Air-Handling Unit, Ductwork, or Plenum
- In-Duct Air Cleaning Systems that Clean Air in the Occupied Zone
- In-Room Air Cleaning Systems
- Mechanical Fibrous Air Cleaning Systems.
- Air Cleaning Systems that Inactivate Infectious Aerosols (additional requirements)

Estimated efficiencies are provided for mechanical filters rated by ASHRAE Standard 52.2

Table 7-1 Infectious Aerosol Removal Efficiency (ε_{PR}) for Mechanical Fibrous Filters

ANSI/ASHRAE Standard 52.2 MERV (Prior to 1/1/2025) MERV-A (After 1/1/2025)	ISO 16890 ePM	Weighted ε_{PR}
<11		0%
11	ePM2.5 50%	60%
12	ePM2.5 65%	71%
13	ePM1 50%	77%
14	ePM1 70%	88%
15	ePM1 85%	91%
16	ePM1 95%	95%
HEPA [a]	ISO 20E [b]	99%

a. High-efficiency particulate air (HEPA) filters are not tested under ANSI/ASHRAE Standard 52.2 [5] or ISO 16890-1 [6]. However, HEPA filters are included here for completeness.
b. Tested in accordance with ISO 29463 [7].

Based on filter efficiency curve and distribution of infections aerosol by particle size

ECA of an air cleaner rated using AHAM AC-1

- AHAM AC-1 determines Clean Air Delivery Rate (CADR) for smoke ($CADR_s$), dust($CADR_d$), pollen($CADR_p$)
- Standard 241 ECA is a *weighted average* – 30% smoke, 30% dust, 40% pollen

$$V_{ACS} = 0.3 \cdot CADR_s + 0.3 \cdot CADR_d + 0.4 \cdot CADR_p$$

Air cleaning systems that inactivate infectious aerosols

In-Duct Ultraviolet Germicidal Irradiation

- Effectiveness: ASHRAE Standard 185.1 using MS2 as the challenge
- Safety: Appendix A

Other (In-Duct Air Cleaning Systems, Upper-Room Ultraviolet Germicidal Irradiation, Other In-Room Air Cleaning Systems)

- Effectiveness: Appendix A (cites ASHRAE Standard 52.2 Appendix L for non-UV air cleaners)
- Safety: Appendix A

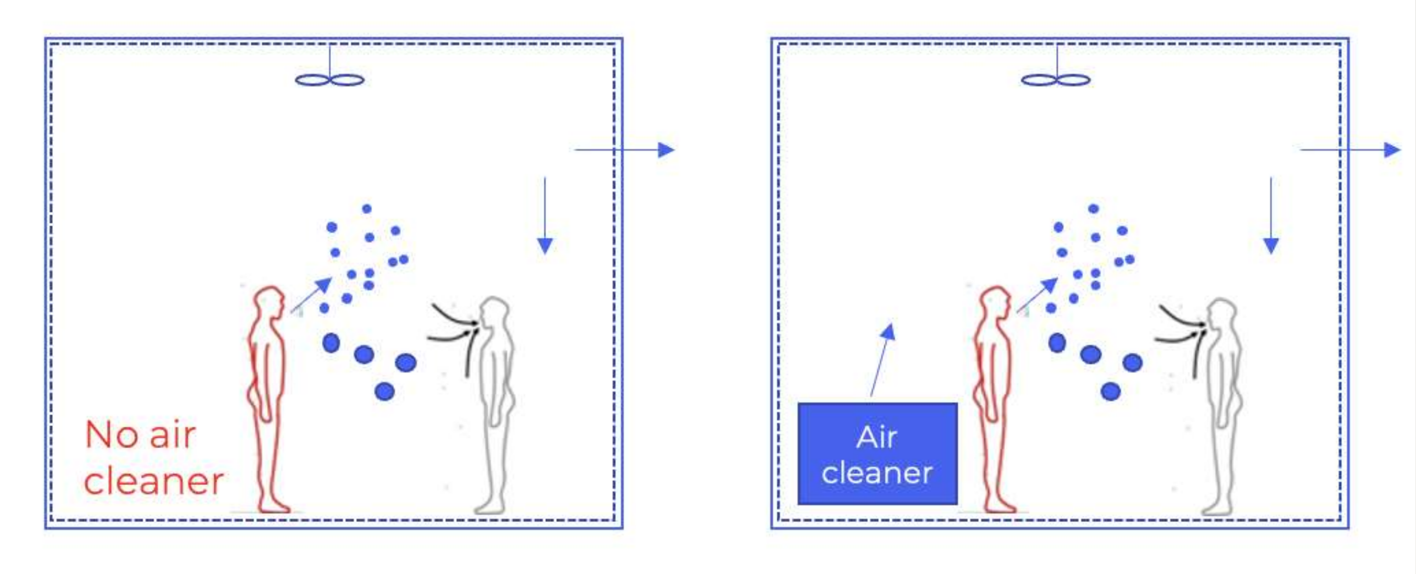
Normative Appendix A Effectiveness and Safety Testing

- Standard: Consensus standards – if not available, custom protocols
- Parity: Same conditions for effectiveness and safety tests
- Testing Laboratory: Compliant with requirements of ISO/IEC 17025 25 or equivalent
- Test chamber: Chamber volume of at least 800 ft^3 (22.7 m^3)
- Test duct: For in-duct air cleaning systems that clean air in the occupied zone, use a test duct that is a recirculating duct connected to or within the test chamber
- Test Microorganism: MS2

Chamber effectiveness testing

- Account for natural decay
- Compare averages of the replicates with the air cleaning system OFF/ON

- For microorganism recovery < limit of detection, use limit of detection in effectiveness calculations



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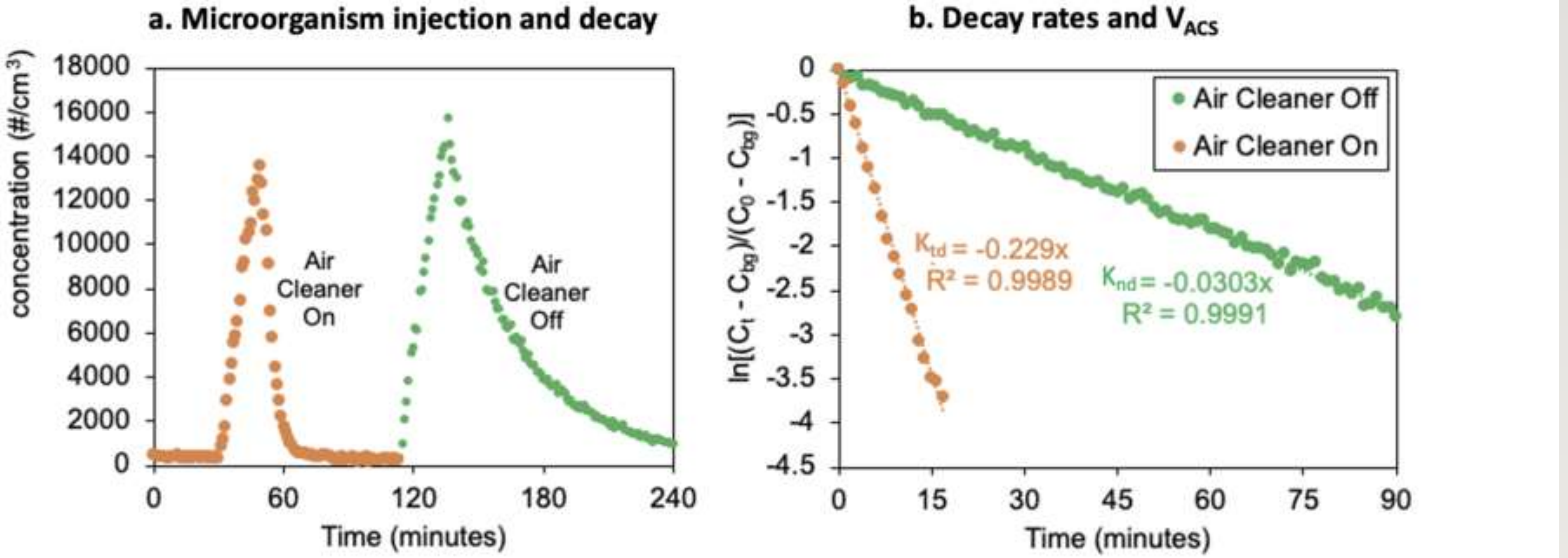
Example: Effectiveness of in-Room air cleaning systems

$$V_{ACS} = V \times \left(k_{td} - k_{nd} \right)$$



V_{ACS} = 258 ft^3/min= 1296 ft^3 x (0.229-0.0303)

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Safety testing requirements

- Chemical Analytes
- Noise (reported only)
- Ultraviolet Radiation
- Combustion byproducts
- Manufacturer's Certification

Table A-1 Required Analytes for Safety Testing

Analyte of Concern	Abbreviation	Test Method	Target
Formaldehyde	HCHO	Formaldehyde shall be measured using any method described in ASTM D8407 [23] that has a detection limit better than 0.5 ppb_v (0.6 $\mu g/m^3$) for a 1-minute sample. Air change must be low enough to detect target emission rate with instrument detection limits.	Emission rate less than 50 µg/h
Ozone	O_3	UL 2998-2020 or equivalent	<5 ppb
Particulate matter count concentration ($\#/m^3$)	Particles greater than 0.3 µm	ISO 14644-14 [24] (duct testing requires isokinetic sampling)	Test results shall not exceed one cleanliness class greater than the empty test chamber or test duct as described in ISO 14644-14, Table 1. Empty chamber shall not measure higher than Class 5.

Standard 62.1-2022 implicitly affects Standard 241 through new addendum n air cleaner test requirements

- New Section 6.3.4 Air Cleaning
  - Particulate filters
    - ASHRAE 52.2 or
    - ISO 16890
  - Gas phase filters
    - ASHRAE Standard 145.2 or
    - ISO 10120-2 or
    - Other approved methods
- Adds to existing ozone emission limit (UL 2998)

- Addendum n supports use of the IAQP as noted in Foreword
  - "The Indoor Air Quality Procedure (IAQP) requires that a mass balance calculation be performed.
  - Any mass balance that includes filtration or air cleaning requires a particle filtration efficiency or gaseous removal efficiency.
  - Addendum n requires that the efficiencies of these devices be tested to current standards."

Assessment, planning, and implementation

- Applies commissioning practices to infection risk mitigation systems
- Sets requirements for Building Readiness Plan development
- Includes assessment of existing V_{ECAi} to determine need for additional controls
- Supporting information
  - Checklists for assessment and commissioning (appendix B)
  - Tracer particle test procedure for determining V_{ECAi} in-place (appendix C)
  - Building Readiness Plan template (appendix E)
  - Equivalent clean air calculator (download at ashrae.org/241-2023)
  - Guidance on assessing energy recovery ventilators (download)
  - Guidance on preventing re-entry of contaminated air (download)

Existing building assessment

- Data Gathering
- Site Observations
- Inventory (Occupied Space, Equipment)
- Potential Separation Spaces
- Ventilation
  - Min OA Requirements
  - Measured / Estimated Airflow
- Coils
- ERVs
- Vent System Controls
- Exhuast
- Air Cleaners
- Control Strategies

Existing Building Planning and Implementation

- Determine V_{ECAi} target
- Determine if additional V_{ECAi} is required
  - V_{ECAi} target – V_{ECAi} existing = V_{ECAi} differential
    - $V_{ECAi,target}$ is determined by Equation 5-1.
    - $V_{ECAi,existing}$ is determined by Equation 6-1 for the system as found
- Select engineering controls if additional V_{ECAi} is required
- Implement and update BRP

New Building or Major Renovation

- Owner's Project Requirements
- Design Review
- Submittals
- Site Observations
- Equipment Checklists
- Functional Performance Tests
- Training
- Systems Manual
- Building Readiness Plan

42 Informative Appendix F: Equivalent Clean Air Calculator

Download at www.ashrae.org/241-2023

Purpose	The basis of this tool is to evaluate systems and equipment to determine the quantity of equivalent clean air is provided to the space, zone, or system to evaluate if it meets the airflow requirements in ASHRAE Standard 241 information. This can be used for New and Existing Systems to show how much they deliver in Infection Risk Management Mode (IRMM) or in Normal Mode.	
Supporting Information		
	Building Readiness Guide	https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf
	ASHRAE Guidance	https://www.ashrae.org/technical-resources/resources
	ASHRAE Standard 241	
Date	June 4, 2023	
Version	v1.0	
IMPORTANT	This tool is intended to simplify the calculation process to determine the target ECAi air quantity for the space, zone or HVAC system to achieve the target established by ASHRAE Standard 241 Table 5-1. This tool also helps calculate the ECAi for the existing and potential required modifications to achieve the target.	
	Universal mask wearing will reduce the bioburden in the space but is not factored into this spreadsheet.	
	Read the DISCLAIMER at bottom of this worksheet	

Phase of the Process		Assessment	Planning	Planning	Planning	Planning	Implement
Name of Space / AHU / Building	**Units**	**EXISTING**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**FINAL SYSTEM**
Description of system or Option		AHU with X,Y,Z	Description	Description	Description	Description	**Description**
Space Type from Standard 241	Type	Classroom	Classroom	Classroom	Classroom	Classroom	Classroom
Target ECAi from Standard 241 (See Instructions for Table)	CFM / Person	40	40	40	40	40	40.0
Area	Sq Ft	1,000	1,000	1,000	1,000	1,000	1,000
Average Ceiling Height	Ft	9	9.0	9.0	9.0	9	**9**
Volume	Cu Ft	9,000	9,000	9,000	9,000	9,000	**9000**
Total Supply Air	CFM	1,000	1,000	1,000	1,000	1,000	**1,000**
Total Outdoor Air	CFM	370	370	370	370	370	**370**
Occupancy - Design (Pz)	Quantity	25	25.0	25.0	25.0	25	**25**
Occupancy - IRMM Target ($P_{z,IRMM}$)	Quantity	25	25.0	13.0	20.0	20	**25**
$V_{ECAi,t,Des}$ Airflow Target - Design Occupancy	CFM	1000	1000.0	1000.0	1000.0	1000	**1000**
$V_{ECAi,t,IRMM}$ Airflow Target - IRMM Target Occ.	CFM	1000	1000.0	520.0	800.0	800	**1000**
Central AHU Filter MERV Rating	MERV	8	13.0	13.0	11.0	13	**13**
Method for Rating Filter	241 or DNFE	241	241	241	241	DNFE	**241**
Filter Pathogen Removal Efficiency	εPR	0.0%	77.0%	77.0%	60.0%	86.0%	77.0%
UV in HVAC - Single Pass Inactivation	%	0.0%	0.00%	0.00%	60.00%	0.00%	**0.00%**
Air Treatment in HVAC (Impacts Space)	CFM	0	0.0	0.0	0.0	0	**0**
Air Treatment Device in Space	CADR	0	0.0	0.0	0.0	0	**0**
Number of Air Treatment Devices in Space	Quantity	0	0.0	0.0	0.0	0	**0**
In Room UV	CFM	0	0.0	0.0	0.0	0	**0**
Number of In Room UV Type	Quantity	0	0.0	0.0	0.0	0	**0**
In Room Air Cleaner (Fan Filter Type)	CADR	0	300.0	0.0	0.0	0.0	**300**
Number of In Room Air Cleaners (Fan Filter type)	Quantity	0	0.0	0.0	0.0	0	**0**
Equivalent Clean Air per Technology			0.0	0.0	0.0		
Outdoor Air	CFM	370.0	370.0	370.0	370.0	370.0	370.0
$V_{ECAi,filter}$	CFM	0.0	485.1	485.1	378.0	541.8	485.1
$V_{ECAi,uv,hvac}$	CFM	0	0	0	151	0	0
$V_{ECAi,rac,hvac}$	CFM	0	0	0	0	0	0
$V_{ECAi,rac,space}$	CFM	0	0.0	0.0	0.0	0.0	0.0
$V_{ECAi,irac,uv}$	CFM	0	0.0	0.0	0.0	0.0	0.0
$V_{ECAi,irac,fanfilter}$	CFM	0	250.0	0.0	0.0	0.0	250.0
Total Equivalent Clean Air	CFM	370	1105	855	899	912	**1105**
Occupancy Count Method (Design or IRMM)	Method	IRMM	IRMM	IRMM	IRMM	IRMM	**IRMM**
ECAi Provided by the Option	**CFM / person**	**14.8**	**44.2**	**65.8**	**45.0**	**45.6**	**44.2**
DOES THIS SYSTEM MEET ECAi TARGET	Pass / Fail	**FAIL**	PASS	PASS	PASS	PASS	**PASS**

Operations

Does not apply to occupancies covered by ASHRAE Standard 62.2

PREPARATION

- BRP on site, accessible, current
- Essential supplies stocked
- Operator training
- Occupant communication
- Operating modes defined:
  - Normal – occupied/unoccupied
  - IRMM – occupied/unoccupied
  - Temporary shutdown

CONTROL DURING IRMM

- Temperature and humidity – maintain design set points when occupied
- Operating schedules
  - On for all occupied hours
  - No on-off control of HVAC fans
- Airflow controls
  - Flushing not required between occupancy periods
  - Account for variable DCV/VAV flows

Determining $V_{ECAi,delivered}$

- Straightforward for some cases, e.g., in-room air filter
- Variable flow systems require special attention
  - Demand control ventilation (DCV)
    - If deactivated, use design or measured outdoor airflow
    - If activated, use the minimum outdoor airflow set point plus airflow to maintain the indoor/outdoor pressure difference
  - Constant/Variable Air Volume (VAV)
    - If constant speed, use resulting measured airflows
    - If allowed to modulate, use minimum airflow set point
- User-determined values → ECA calculator

Maintenance

- More frequent performance of some items, e.g., system outdoor airflow in IRMM
- New requirements for air cleaners and separation spaces

Table 9-2 Minimum Maintenance Activity and Frequency for Additional Engineering Controls and Associated Components While in Use

Engineering Control	Inspection/Maintenance Task	Frequency
In-room air cleaners	Verify unit is in appropriate location and operating as intended per the *BRP*. Confirm that the air cleaner is operating at the speed or setting assumed in the V_{ECAi} calculation. Maintain systems and equipment and verify performance per manufacturer's instructions. Visually inspect intake for debris and clean as necessary.	Monthly
Ultraviolet (UV) germicidal irradiation	Maintain systems and verify performance and safety per manufacturer's instructions and in accordance with ANSI/IES RP-44-21 [11] and ANSI/IES RP-27.1.22 [20] or equivalent. Adjust, clean, and replace equipment as needed.	Assess quarterly or per manufacturer's recommended interval
All air cleaning systems and equipment (including in-room, in-duct, and UV air cleaners)	Maintain systems and equipment and verify performance per manufacturer's instructions. Adjust, clean, and replace equipment as needed. If equipment cannot be repaired, remove equipment from service and use a substitute engineering control to maintain V_{ECAi} in occupied space.	Assess quarterly or per manufacturer's recommended interval
Separation space	The designated temporary separation areas shall be tested for negative pressure whenever an infected individual is present.	As used

Additional requirements for dwelling units

- For Systems and Spaces with vulnerable or infected occupants
  - Block HVAC systems serving multiple units to separation space
  - Infected occupant – fully enclosed separation area
  - Provide separation area V_{ECAi} based on health-care patient room ECAi
    - Rest of space treated as Dwelling
  - Vulnerable occupant – fully enclosed separation area
    - Provide VECAi based on health-care patient room ECAi throughout dwelling
- Lids on toilets
- Water in plumbing traps

Summary – the Standard 241 process

- Assess facility – condition and existing equivalent clean air delivered
- Determine target equivalent clean air required by space and system
- Determine need for additional equivalent clean air
- Determine the best option for providing required equivalent clean air using outdoor air, particle filtration, and air cleaners tested as required, and operational measures
- Prepare a Building Readiness Plan to document assessment and decisions
- Perform repair and maintenance as needed and required
- Implement upgrades if needed

Broader implications of Standard 241

- Equivalent clean airflow
  - Quantifies the combined effect of multiple controls
  - Creates potential for better IAQ with lower energy use
  - Applies to all aspects of IAQ
- Infection risk management mode
  - Introduces resilience into IAQ standards
  - Also applicable to wildfire smoke and other acute IAQ events
- Air cleaner testing
  - Requirements for quantifying effectiveness and safety
  - Enable use of alternatives to ventilation

Future

- Communication – publications, presentations, web page
- Pilot testing
- ANSI certification
- Referencing in ASHRAE 62.1/62.2
- Adoption in code

- Continuous maintenance
  - Performance path
  - Energy use requirements
  - Add more space types
  - Expand air distribution content
  - Update air cleaner testing requirements to reference new standards

Thank you!

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ashrae.org/241