



BSR/ASHRAE Standard 241P

Public Review Draft

Control of Infectious Aerosols

**Second Public Review (October 2026)
(Draft Shows Complete Proposed New Standard)**

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at <https://www.ashrae.org/technical-resources/standards-and-guidelines/public-review-drafts> and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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FOREWORD FOR PUBLIC REVIEW

Standard 241-2023 was passed under an expedited process in response to the COVID19 pandemic. Because of the expedited process, it did not qualify for ANSI certification. ASHRAE is now processing a revision to that standard using the normal ANSI/ASHRAE procedures. The overall objectives, title, purpose and scope of the standard remain the same.

The standard was originally put out for public review and received many comments. Based on the number and quality of the comments, the project committee decided to pull back that version. This second full public review draft has greatly improved the draft and is being circulated for public review.

1. PURPOSE

- 1.1 The purpose of this standard is to establish minimum requirements for control of infectious aerosols to reduce risk of disease transmission in the *occupiable space* in new buildings, existing buildings, and major renovations to existing buildings, including requirements for both outdoor air system and *air cleaning* system design, installation, commissioning, operation, and maintenance.
- 1.2 This standard defines the amount of *equivalent clean airflow* necessary to substantially reduce the risk of disease transmission during *infection risk management mode*.

2. SCOPE

- 2.1 This standard
 - a. Does not address requirements for maintaining acceptable indoor air quality
 - b. Addresses only indoor *long-range transmission* resulting from inhalation of infectious aerosol emitted by an infector who is not in close proximity to a susceptible occupant
 - c. May not substantially reduce transmission risk in all situations due to the diversity of infectious agents and personal susceptibility
- 2.2 This standard does not determine the conditions under which *infection risk management mode* should be invoked.
- 2.3 No requirement of this standard shall be used to circumvent any health, safety or comfort regulations required by the *authority having jurisdiction*.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

- 3.1 **General.** Certain terms, abbreviations, and acronyms are defined in this section of the standard. When the tense or number of the term differs from the defined terms, the defined term still applies. These definitions are applicable to all sections of the standard except where specified.
 - 3.1.1 **Coordination.** Terms not defined in this standard that are defined in ANSI/ASHRAE Standard 62.1 ¹, ANSI/ASHRAE Standard 62.2 ², ANSI/ASHRAE/ASHE Standard 170 ³, or other referenced standards, shall have the meanings assigned to them in those standards. Where terms are not defined in those documents or this standard, they shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meaning shall be based on standard American English language usage as documented in an unabridged dictionary accepted by the *authority having jurisdiction*.
- 3.2 **Definitions**

air cleaning: reducing the concentration of infectious aerosols in the air through infectious aerosol capture and removal or by infectious aerosol inactivation.

authority having jurisdiction (AHJ): the agency or agent responsible for determining compliance with this standard.

building readiness plan (BRP): a plan that documents the engineering and non-engineering controls that the facility systems will use for the facility to achieve its goals.

equivalent clean airflow: the theoretical flow rate of pathogen-free air that, if distributed uniformly within a volume of interest, would have the same effect on infectious aerosol concentration as the sum of actual outdoor airflow, filtered airflow, and inactivation of infectious aerosols.

fibrous filters: air filters that employ an air permeable media such as a fibrous fabric or porous membrane to capture particles from the air, inclusive of those filters that contain an initial one-time electrical charge (known as electret filters), as well as filters containing additives for antimicrobial or other performance purposes, but not inclusive of those filters relying on external power other than that used to move air through the filter.

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.

infection risk management zone (IRMZ): a defined sub-volume within the *occupiable space* of a building into which the required *equivalent clean airflow* is to be delivered.

long-range transmission: disease transmission that is due to aerosols emitted by an infector who is not near a susceptible occupant.

occupiable space: an indoor space intended for human activities, excluding spaces that are intended to be occupied occasionally and for short periods of time (such as storage rooms, equipment rooms, and emergency exit ways).

vulnerable occupant: any occupant who is considered by themselves or by a health professional to be at greater risk of harm from being infected.

3.3 Acronyms and Abbreviations

ACCA	Air Conditioning Contractors of America Association, Inc.
ACH _T	target air changes per hour
AD	aerosol detector
AHAM	Association of Home Appliance Manufacturers
AHJ	<i>authority having jurisdiction</i>
AHU	air-handling unit
ASTM	ASTM International
BAS	building automation system
BRP	<i>building readiness plan</i>
CADR	clean air delivery rate
cfm	cubic feet per minute
CxP	commissioning provider
DCV	demand-controlled ventilation
ECAi	required <i>equivalent clean airflow</i> per person for infection risk mitigation
EPA	U.S. Environmental Protection Agency
ePM	particulate matter efficiency
ε _{PR}	infectious aerosol reduction efficiency
ERV	energy recovery ventilation
FPT	functional performance test
ft	foot or feet
GUV	germicidal ultraviolet
HCHO	formaldehyde

HEPA	high efficiency particulate air
IAQ	indoor air quality
IES	Illuminating Engineering Society
<i>IRMM</i>	<i>infection risk management mode</i>
<i>IRMZ</i>	<i>infection risk management zone</i>
ISO	International Organization for Standardization
L/s	liters per second
k_{nd}	infectious microorganism decay rate without <i>air cleaning</i> system operating
k_{td}	infectious microorganism decay rate with <i>air cleaning</i> system operating
L_{off}	first-order loss rate for the chemical that includes both air change and surface losses
m	meter(s)
mCADR	microbial clean air delivery rate
MERV	minimum efficiency reporting value
O ₃	ozone
O&M	operations and maintenance
OPR	owner's project requirements
$P_{Z,IRMM}$	number of people in the <i>occupiable space</i> in <i>IRMM</i>
TAB	testing, adjusting, and balancing
UL	Underwriters Laboratory
V	test chamber volume
V_{ACS}	<i>air cleaning</i> system equivalent clean airflow rate
$V_{ACS,sys}$	multizone <i>air cleaning</i> system equivalent clean airflow rate
V_{ECAi}	minimum <i>equivalent clean airflow</i> rate required to mitigate <i>long-range transmission</i> risk in <i>IRMM</i>
V_{NV}	outdoor airflow rate from natural ventilation system
$V_{OA,sys}$	the outdoor air intake flow rate
V_{RC}	recirculated airflow rate cleaned by the <i>air cleaning</i> system
v_f	air handling system fraction

4. COMPLIANCE

4.1 Prerequisites

- 4.1.1** *Occupiable spaces* shall meet the requirements of the applicable version of ANSI/ASHRAE Standard 62.1^{1,4}, ANSI/ASHRAE Standard 62.2^{2,4}, or ANSI/ASHRAE/ASHE Standard 170^{3,4}, as determined by its occupancy and date of construction or major renovation, or as determined by the *authority having jurisdiction (AHJ)*. The *AHJ* may approve the use of an equivalent standard as an alternate.

4.2 Requirements

- 4.2.1** All *occupiable spaces*, except as noted, shall comply with the requirements below.
- 4.2.1.1** Compliance with Sections 5 and 6 shall be required for all spaces.
 - 4.2.1.2** Compliance with Section 7 shall be required for all equipment and devices that contribute towards *equivalent clean airflow*, except those that do so exclusively by supplying outdoor air or exhausting indoor air.
 - 4.2.1.3** Compliance with Section 8 and Section 9 shall be required for all spaces except for those required to comply with Section 10.
 - 4.2.1.4** Compliance with Section 10 shall be required for all non-institutional, non-transient residential occupancies, such as those within the scope of ANSI/ASHRAE Standard 62.2².

- 4.2.2 Application and installation of systems or equipment shall be carried out in accordance with the manufacturer's installation, operation, and maintenance instructions.
- 4.2.3 Those dwelling units complying with ANSI/ASHRAE Standard 62.2² (including Informative Appendix E) are deemed to comply with this standard.

5. EQUIVALENT CLEAN AIRFLOW FOR INFECTION RISK MITIGATION

5.1 Minimum Equivalent Clean Airflow Rate

- 5.1.1 Minimum *equivalent clean airflow* rate required for each *IRMZ* to mitigate *long-range transmission* risk in *IRMM* (V_{ECAi}) shall be determined in accordance with Equation 5-1.

$$V_{ECAi} = ECAi \times P_{Z,IRMM} \quad (5-1)$$

where

- V_{ECAi} = minimum *equivalent clean airflow* rate required in the *occupiable space* to mitigate *long-range transmission* risk in *IRMM*, cfm (L/s)
- $ECAi$ = *equivalent clean airflow* rate required per person in *IRMM* from Table 5-1, cfm (L/s) per person
- $P_{Z,IRMM}$ = number of people in the *occupiable space* during *IRMM*. Unless the *Building Readiness Plan (BRP)* specifies a lower occupancy limit, the following defaults shall apply. $P_{Z,IRMM}$ shall default to the number of occupants used to calculate the ventilation rate per the applicable standard (see Section 4.1.1) or the design occupancy. For multi-stall restrooms, the number of people shall be calculated as the total count of plumbing fixtures, including water closets, urinals, and sinks, present in the space.
- 5.1.2 Where the occupancy category for a proposed *IRMZ* is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density and activities shall be used.
- 5.1.3 Where there are multiple occupancy categories within an *IRMZ*, the highest *equivalent clean airflow* rate required per person in *IRMM* of the occupancy categories within the *IRMZ* shall be used.
- 5.1.4 Where the occupancy category for a proposed *IRMZ* involves group vocalization above a conversational level, the *equivalent clean airflow* rate required per person in *IRMM* shall be multiplied by a factor of 2.
- 5.1.5 For public toilets, the minimum *equivalent clean airflow* rate shall be met using one or a combination of exhaust airflow and in-room *air cleaning* systems.
- 5.1.6 For *IRMZs* (other than those complying with Section 10) where occupants known to be infected are permitted during *IRMM*, the *equivalent clean airflow* rate required per person shall be 100 cfm (50 L/s) per infected person.

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

Occupancy Category	ECAi	
	cfm/person	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
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
Toilets		
Toilets – Public ^a	70	35

a. Rate is for a multi-stall restroom intended to be occupied by more than one person at a time.

6. AIR DISTRIBUTION AND NATURAL VENTILATION

6.1 Infection Risk Management Zone (IRMZ). The *occupiable* space shall be subdivided into one or more *IRMZs*. Each *IRMZ* shall not be larger than the connected volume enclosed on all sides by walls, floors, and ceilings, and shall be assigned an air distribution category as described in Table 6-1.

6.2 Clean Airflow Rate. The clean airflow rate to each *IRMZ* within a building shall be greater than or equal to the minimum *equivalent clean airflow* required, as expressed by Equation 6-1.

$$\Sigma[v_f \times (V_{OA,sys} + V_{ACS,sys})] + \Sigma V_{TCA} + \Sigma V_{ACS} + V_{NV} \geq V_{ECAi} \quad (6-1)$$

where

- v_f = the fraction of air supplied to the *IRMZ* by the air handling system, calculated as the airflow rate supplied to the *IRMZ* divided by the total supply airflow rate of the air handling system
- $V_{OA,sys}$ = the total outdoor airflow rate supplied by the air handling system, cfm (L/s)
- $V_{ACS,sys}$ = the *equivalent clean airflow* rate for an *air cleaning* system, a fraction of whose output is distributed to the *IRMZ* by an air handling system, determined by Section 7, cfm (L/s)
- V_{TCA} = the *equivalent clean airflow* rate in excess of the *equivalent clean airflow* rate required in one *IRMZ* that has been transferred to the *IRMZ*, cfm (L/s)
- V_{ACS} = the *equivalent clean airflow* rate for a system supplying clean air to the *IRMZ*, determined per Section 7, cfm (L/s)
- V_{NV} = the total outdoor airflow rate from all natural ventilation systems supplied directly to the *IRMZ*, determined per Section 6.4, cfm (L/s)
- V_{ECAi} = the minimum *equivalent clean airflow* rate required, determined per Section 5, cfm (L/s)

6.3 Air Distribution Categories. Each *IRMZ* shall be assigned an air distribution category as described in Table 6-1.

6.3.1 Spatial Uniformity. An *IRMZ* shall only have one air distribution category at a time.

Informative Note: It is possible for an *IRMZ* to have different air distribution patterns at different times; this may be the result of different seasons (e.g., heating or cooling mode), the presence of natural ventilation openings, or alternate occupancy modes.

6.3.2 Accommodation. The design shall acknowledge the different operating modes and accommodate the potential for different air distribution patterns. This shall be documented in the *BRP*.

Table 6-1 Air Distribution Category

Air Distribution Category	Description	Typical System Types
Well-mixed	Airflow pattern characterized by recirculation within the <i>IRMZ</i>	Overhead mixing, underfloor mixing
Natural	Airflow pattern characterized by buoyant updraft within the <i>IRMZ</i>	Natural ventilation, horizontal displacement
Cross flow	Airflow pattern characterized by lateral movement of air throughout the <i>IRMZ</i>	Toilet room, kitchen transfer air
Downflow	Airflow pattern characterized by downward movement of air throughout the <i>IRMZ</i>	Clean room
Upflow	Airflow pattern characterized by upward movement of air throughout the <i>IRMZ</i>	Underfloor or sidewall displacement

6.4 Natural Ventilation. Natural Ventilation systems shall be designed in accordance with the methods described in ANSI/ASHRAE Standard 62.1¹, ANSI/ASHRAE/ASHE Standard 170³, or an engineering analysis approved by the *AHJ*.

6.4.1 Fans. In-room fan-assisted natural ventilation systems shall determine the equivalent outdoor airflow rate through engineering analysis.

6.4.2 Openings. Natural ventilation openings shall

- a. Be separated by a minimum of 3 ft (1 m) from openings serving different rooms
- b. Not be located within sheltered, recessed or enclosed areas

6.5 Mixed-Mode Ventilation. Mixed mode natural ventilation systems shall be evaluated independently under all operating conditions. The systems shall be designed in accordance with the natural ventilation and mechanical

ventilation methods described in ANSI/ASHRAE Standard 62.1¹, ANSI/ASHRAE/ASHE Standard 170³, or an engineering analysis approved by the *AHJ*.

- 6.5.1 Zoned Mixed-Mode Ventilation.** In zoned or spatial mixed-mode systems, where the ventilation mode varies among different parts of the *occupiable space*, the *occupiable space* shall be subdivided into different *IRMZs*. Compliance with Equation 6-1 shall be demonstrated for each *IRMZ* independently.
- 6.5.2 Changeover Mixed-Mode Ventilation.** In changeover or temporal mixed-mode systems, where the ventilation mode for the whole *IRMZ* alternates according to space needs, compliance with Equation 6-1 shall be demonstrated individually for natural and mechanical ventilation operating modes.
- 6.5.3 Concurrent Mixed-Mode Ventilation.** In concurrent mixed-mode systems (e.g., semi-passive spaces), where a combined approach is used, compliance with Equation 6-1 shall be demonstrated with the combined effect of natural and mechanical ventilation systems.
- 6.6 Transfer Air.** Clean air delivered to one *IRMZ* in excess of the *equivalent clean airflow* rate required may be transferred to another *IRMZ* to satisfy the *equivalent clean airflow* rate required.
- 6.7 Air Distribution Requirements for Air Cleaning Systems**
 - 6.7.1** *Air cleaning systems* shall be installed in accordance with the manufacturer's instructions.
 - 6.7.2 Determination of the Air Distribution Category.** The air distribution category shall be determined with the *IRMM* mitigation implemented including all sources of V_{ECAi} .
 - 6.7.3 Placement.** The placement of an in-room *air cleaning* device impacts the performance and efficiency of the V_{ECAi} delivery. Placement of in-room *air cleaning* devices shall be as specified in Sections 6.7.3.1 through 6.7.3.5.
 - 6.7.3.1 In-Room Air Cleaning Inlets.** The inlet to an in-room *air cleaning* device shall not be located adjacent to, or within the direct airstream of, a supply of *equivalent clean airflow*, regardless of whether it is delivered from the air handling systems or another in-room *air cleaning* system.
 - 6.7.3.2 In-Room Air Cleaning Outlets and Room Exhaust.** The outlet of an in-room *air cleaning* device shall not direct air into a room exhaust.
 - 6.7.3.3 Ceiling Mounted Passive Air Cleaning Systems.** An *air cleaning* device (e.g., GUV) located, near the ceiling, that uses passive airflow distribution shall not be used in an *IRMZ* that has an upflow air distribution category or an *IRMZ* where the presence of buoyance creates a stratified zone.
 - 6.7.3.4 Near Floor Air Cleaning System.** *Air cleaning* devices located within 3.3 ft (1.0 m) of the floor that deliver air, such that it remains low in the space, shall not be used in an *IRMZ* that has a downflow air distribution category.
 - 6.7.3.5 In-Room Air Cleaning Outlets and Obstructions.** The outlets to in-room *air cleaning* devices shall be mounted such that they distribute air away from walls in close proximity and other local obstructions.

7. AIR CLEANING SYSTEMS

- 7.1 General.** The effectiveness and safety of *air cleaning* systems that contribute towards meeting zone minimum *equivalent clean airflow* requirements of Section 6 shall be determined in accordance with this section and Normative Appendix A. The requirements listed in this standard shall supersede specific requirements listed in the consensus standards referenced in this section and Normative Appendix A.
- 7.2 Air Cleaning System Effectiveness**

The *equivalent clean airflow* rate, V_{ACS} , from *air cleaning* systems used in Section 6 to determine total zone *equivalent clean airflow* shall be determined in accordance with this section.

 - 7.2.1 Air Cleaning Systems with Single-Pass Efficiency.** *Air cleaning* systems with an effectiveness that is characterized by the manufacturer with a single-pass efficiency shall have an effectiveness reported as an infectious aerosol reduction efficiency (ϵ_{PR}) as determined in accordance with this section and Normative Appendix A. The *equivalent clean airflow* rate shall be calculated in accordance with Equation 7-1.

$$V_{ACS} = \left[\frac{\epsilon_{PR}}{100} \right] \times V_{RC} \quad (7-1)$$

where

- V_{ACS} = *air cleaning system equivalent clean airflow rate due to the air cleaning system, cfm (L/s)*
- ϵ_{PR} = *infectious aerosol reduction efficiency, determined in accordance with Section 7.2.1.2 through Section 7.2.1.4, %*
- V_{RC} = *recirculated airflow rate cleaned by the air cleaning system, cfm (L/s)*

7.2.1.1 Where multiple *air cleaning* systems with a single-pass reduction efficiency are installed in series within the same airflow path, the infectious aerosol reduction efficiency (ϵ_{PR}) shall be determined in accordance with the appropriate version of Equation 7-2.

One System

$$\epsilon_{PR} = \epsilon_{PR,1} \quad (7-2a)$$

Two Systems

$$\epsilon_{PR} = \left\{ 1 - \left[1 - \left(\frac{\epsilon_{PR,1}}{100} \right) \right] \times \left[1 - \left(\frac{\epsilon_{PR,2}}{100} \right) \right] \right\} \times 100 \quad (7-2b)$$

N Systems

$$\epsilon_{PR} = \left\{ 1 - \prod_{j=1}^N \left[1 - \left(\frac{\epsilon_{PR,j}}{100} \right) \right] \right\} \times 100 \quad (7-2c)$$

where $\epsilon_{PR,j}$ is the infectious aerosol reduction efficiency of the j^{th} *air cleaning* system determined in accordance with Section 7.2.1.3 or Section 7.2.1.4.

7.2.1.2 Single-Pass Particle Reduction Testing. *Air cleaning* system equipment with an effectiveness that is characterized by the manufacturer by a single-pass particle efficiency test shall be tested in accordance with one of the following applicable consensus standards:

- ANSI/ASHRAE Standard 52.2⁵ with Appendix J
- ISO 16890-1⁶

Testing shall be conducted at the maximum face velocity that will be used with the *air cleaning* system in the application setting.

The infectious aerosol reduction efficiency (ϵ_{PR}) of *air cleaning* systems shall be determined in accordance with Equation 7-3 or Table 7-1.

$$\epsilon_{PR} = W_{E1}\epsilon_{E1} + W_{E2}\epsilon_{E2} + W_{E3}\epsilon_{E3} \quad (7-3)$$

where

- ϵ_{PR} = *infectious aerosol reduction efficiency, %*
- W_{E1} = *fraction of the infectious aerosol in the 0.3 to 1.0 micrometer (μm) particle size range, dimensionless*
- W_{E2} = *fraction of the infectious aerosol in the 1.0 to 3.0 μm particle size range, dimensionless*
- W_{E3} = *fraction of the infectious aerosol in the 3.0 to 10.0 μm particle size range, dimensionless*
- ϵ_{E1} = *particle removal efficiency in the 0.3 to 1.0 μm particle size range, %*
- ϵ_{E2} = *particle removal efficiency in the 1.0 to 3.0 μm particle size range, %*
- ϵ_{E3} = *particle removal efficiency in the 3.0 to 10.0 μm particle size range, %*

The weighting fractions for use in Equation 7-3 shall be $W_{E1} = 0.30$, $W_{E2} = 0.30$, and $W_{E3} = 0.40$.

Exception to Section 7.2.1.2: For high efficiency particulate air (HEPA) filters tested under ISO 29463-1⁷, the infectious aerosol reduction efficiency (ϵ_{PR}) shall be in accordance with Table 7-2. For HEPA filters tested under standards from the Institute of Environmental Sciences and Technology (IEST)⁸ or the U.S.

Department of Defense⁹, ϵ_{PR} shall be 99%.

Table 7-1 Infectious Aerosol Removal Efficiency (ϵ_{PR}) for Fibrous Filters Tested in Accordance with ANSI/ASHRAE Standard 52.2⁵ with Appendix J or with ISO 16890-1⁶

MERV-A	ISO 16890-1 ⁶ ePM	Weighted ϵ_{PR}
<8-A	<ePM10 50%	0%
8-A	ePM10 50%	34%
9-A	ePM10 60%	41%
10-A	ePM10 70%	47%
11-A	ePM2.5 50%	60%
12-A	ePM2.5 65%	71%
13-A	ePM1 50%	77%
14-A	ePM1 70%	88%
15-A	ePM1 85%	91%
16-A	ePM1 95%	95%

Table 7-2 Infectious Aerosol Removal Efficiency (ϵ_{PR}) for Fibrous Filters Tested in Accordance with ISO 29463-1⁷

Filter Class and Group	ϵ_{PR}
ISO 05 E	85%
ISO 10 E	90%
ISO 15 E	95%
ISO 20 E through ISO 75 H	99%

7.2.1.3 Single-Pass Bioaerosol Reduction Testing. *Air cleaning* systems that do not contain their own air moving equipment and have a performance that is characterized by the manufacturer with a single-pass efficiency test for viable bioaerosol reduction shall be tested in accordance with one of the following:

7.2.1.3.1 The methodology of ANSI/ASHRAE Standard 52.2⁵ with Appendix L (found in Addendum c to ANSI/ASHRAE 52.2-2017).

7.2.1.3.2 The methodology of ANSI/ASHRAE Standard 185.1¹⁰ for single pass efficiency.

For *air cleaning* systems tested in accordance with this section, the resulting viable bioaerosol reduction shall be equivalent to the *air cleaning* system's infectious aerosol reduction efficiency (ϵ_{PR}).

7.2.2 Air Cleaning Systems with an Equivalent Clean Airflow Rate Performance. The effectiveness of *air cleaning* systems characterized by the manufacturer with an *equivalent clean airflow* rate (V_{ACS} , cfm [L/s]) shall be determined in accordance with this section and Normative Appendix A.

7.2.2.1 Particle Reduction Chamber Testing. *Air cleaning* systems with a performance that is characterized by the manufacturer with a particle chamber test (systems that depend on only *fibrous filter* components and air moving equipment) shall be rated in accordance with the methodology of ANSI/AHAM AC-1¹¹. For *air cleaning* systems with a $CADR_s > 600$ cfm, $CADR_d > 600$ cfm, or $CADR_p > 600$ cfm, the ANSI/AHAM AC-1¹¹ method shall be used with a chamber having a ratio of test chamber volume to the *air cleaning* system *equivalent clean airflow* rate greater than $1.7 \text{ ft}^3/\text{cfm}$ ($0.101 \text{ m}^3/[\text{L/s}]$).

The *equivalent clean airflow* rate shall be determined using the results from this performance test in accordance with Equation 7-4 at the speed of intended use during *IRMM*.

$$V_{ACS} = (W_s \times CADR_s) + (W_d \times CADR_d) + (W_p \times CADR_p) \quad (7-4)$$

where

V_{ACS}	=	air cleaning system equivalent clean airflow rate, cfm (L/s)
W_s	=	weighting factor for tobacco smoke, dimensionless
W_d	=	weighting factor for dust, dimensionless
W_p	=	weighting factor for pollen, dimensionless
$CADR_s$	=	clean air delivery rate for tobacco smoke, cfm (L/s)
$CADR_d$	=	clean air delivery rate for dust, cfm (L/s)
$CADR_p$	=	clean air delivery rate for pollen, cfm (L/s)

The weighting fractions for use in Equation 7-4 shall be $W_s = 0.30$, $W_d = 0.30$, and $W_p = 0.40$. If the CADR is not reported for any of the challenge aerosols, the CADR value to be used in Equation 7-4 for that aerosol shall be zero.

7.2.2.2 Bioaerosol Reduction Chamber Testing. *Air cleaning* systems with a performance that is characterized by the manufacturer with a bioaerosol chamber test shall be rated in accordance with Normative Appendix A and the methodology of one of the following consensus standards:

- a. ANSI/AHAM AC-5 ¹²
- b. ANSI/ASHRAE Standard 185.3 ¹³

For *air cleaning* systems tested using ANSI/AHAM AC-5 ¹², the reported mCADR shall be the *equivalent clean airflow rate* (V_{ACS}). For *air cleaning* systems tested in accordance with ANSI/ASHRAE Standard 185.3 ¹³, the CADR shall be the *equivalent clean airflow rate* (V_{ACS}).

V_{ACS} shall be calculated using data collected from a test lasting at least one hour (following the bioaerosol nebulization period) or until a minimum of 2 log₁₀ (99%) bioaerosol reduction is achieved (comparing the time-matched bioaerosol sampling recoveries from the average of *air cleaning* system ON and *air cleaning* system OFF test replicates).

7.2.3 Worst Air Cleaning System Performance. When the test method used to rate the efficiency or V_{ACS} of the *air cleaning* system is based on initial performance, the performance shall be depreciated to the manufacturer determined and documented worst performance during useful life to account for degradation over the lifetime of the air cleaner under recommended maintenance procedures and the scope of the system's intended use.

Exception to 7.2.3: *Fibrous filters* rated to ANSI/ASHRAE Standard 52.2 ⁵ with Appendix J (MERV-A) or to ISO 16890-1 ⁶ (ePM1, ePM2.5, and ePM10) in accordance with Section 7.2.1.2 for the intended air velocity. Additionally, HEPA filters tested under ISO 29463-1 ⁷ or under standards from the Institute of Environmental Sciences and Technology (IEST) ⁸ or the U.S. Department of Defense ⁹.

7.3 Air Cleaning System Safety. Safety testing requirements for *air cleaning* systems shall be in accordance with Normative Appendix A. The following installation requirements shall also apply.

7.3.1 Germicidal Ultraviolet Radiation. In-room *air cleaning* systems that generate electromagnetic radiation into the room with a wavelength between 100 and 400 nm shall be installed and operated in accordance with ANSI/IES RP-44-21 ¹⁴. These systems shall not result in exposures to room occupants that exceed the threshold limit values (TLVs) in the 2025 ACGIH Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) ¹⁵ for the wavelength(s) emitted by the system. The GUV TLVs shall not be exceeded in the space served by the system at a height of 6 ft (1.8 m) or below. Conformance with the TLVs shall be confirmed by measurements as described in ANSI/IES RP-27.1-22 ¹⁶ and ANSI/IES RP-44-21 ¹⁴. The GUV system installer shall provide documentation that these requirements have been met.

7.3.2 Combustion Byproducts. *Air cleaning* systems that utilize any form of combustion, or heat surfaces in contact with the airflow greater than 2240°F (1500 K), shall not increase the concentration of nitrogen oxides and carbon monoxide by more than 20% over baseline concentrations with the *air cleaning* system not

running. The manufacturer shall provide specific documentation that these requirements have been met.

- 7.4 Air Cleaning Systems with Air Moving Equipment.** *Air cleaning* systems that include factory-installed air moving equipment shall be tested for sound power level at the speed of intended use during *IRMM*. An average A-weighted sound power level (unit: dB re 1 pW) shall be determined from sound pressure level measurements at a distance of 3.3 ft (1.0 m) from the *air cleaning* system per ANSI/AHAM AC-2¹⁷. The sound power level shall be included in the test report.

8. ASSESSMENT, PLANNING, AND IMPLEMENTATION

- 8.1 Building Readiness Plan (BRP).** The *BRP* shall be created after the assessment, planning, and implementation phases to describe the engineering and non-engineering controls that the facility's systems will use to achieve its target *equivalent clean airflow* for infection control ($V_{ECAi,target}$). The *BRP* shall be either a standalone document or a section of an existing emergency operations planning document. The *BRP* shall be reviewed annually or when there are changes to the engineering controls or a modification to the $V_{ECAi,target}$ used by the facility and its systems, whichever is more frequent.
- The engineering controls section shall include the operations and maintenance (O&M) procedures (including operating schedules), ventilation system operating schedules and airflow values, *air cleaning* technologies used with included locations and intended speed or intensity levels, filtration MERV rating and rack sizing, final design drawings, critical asset inventory management plan, maintenance schedules based on manufacturer instructions, the maintenance requirements and frequencies provided in Section 9.2.2, and any changes made to the system for *infection risk management mode (IRMM)* as opposed to normal mode of operation (which is how the system is operating when it is not in *IRMM*). The *BRP* shall also include a *IRMZ*-level ventilation matrix that specifies the V_{ECAi} target for *IRMM*. If V_{ECAi} is to be provided by standalone systems (e.g., in-room air filters), then the *BRP* must also include O&M schedules for all such systems. The *BRP* shall include any testing or safety documents required by this standard.
 - The non-engineering controls section shall include any requirements for allowed changes in building occupancy levels ($P_{z,IRMM}$), personal protective equipment use, physical distancing, and cleaning.
 - The *BRP* shall include a process for managing known or potentially infected occupants, either in this facility or by relocation to another facility.

Informative Note: See Informative Appendix E, "Building Readiness Plan Template."

8.2 Existing Buildings Assessment, Planning, and Implementation

- 8.2.1 Existing Buildings.** The requirements of this section apply to buildings and their systems that were constructed or renovated before the adoption of this standard. The processes in Section 8.2 shall be followed for an existing building or system to be deemed to comply with this standard. The existing building and its system shall be assessed for current operation and feasibility of potential engineering controls that contribute to the required V_{ECAi} . In the planning phase, potential engineering controls shall be evaluated, selected, and implemented. In the commissioning phase, the systems shall be verified as operational. All information shall be documented in the *BRP*. Detailed requirements for components of the assessment, planning and implementation for existing buildings are listed in Normative Appendix B.
- 8.2.2 Building Alterations or Change of Use.** The systems contributing to V_{ECAi} shall be reevaluated as necessary when any of the following occur:
- Buildings or systems are altered
 - Changes are made to building use or space occupancy category
 - A significant change in occupancy density occurs
 - Other changes are made that are inconsistent with system design assumptions
- 8.2.3 Existing Building Assessment.** The existing building and its systems shall be assessed through document review and site observations to determine how the spaces are currently used and how the facility, equipment, and systems are currently operating, and to identify potential engineering controls that contribute to the required V_{ECAi} .

8.2.3.1 Data Gathering

- a. The following documents, if available, shall be obtained and reviewed:
 1. Record or as-built documents for the mechanical, electrical, and plumbing systems
 2. Most recent design documents for the current configuration, and the original design documents used for construction.
 3. Commissioning documents that include the functional performance tests (FPTs), commissioning report, and systems manual
 4. Building automation systems (BAS) sequences of operation and control diagrams
 5. Testing, adjusting, and balancing (TAB) reports
- b. The following information shall be discussed with the owner and operator in a meeting:
 1. Operating issues with the systems as identified by the facility staff or service contractors
 2. Ongoing renovation projects
 3. Planned renovation projects
 4. BAS trending that is available or that can be made available

8.2.3.2 Site Observations

- a. A walk of the facility shall be undertaken to determine what HVAC systems are installed, and to observe how the systems are operating.
- b. Evaluation of the air-side and water-side systems shall be completed.

8.2.3.3 Occupied Space Inventory. Each occupied space shall be categorized as one of the nonresidential occupancy categories in Table 5-1 of this standard and one of the following:

- a. A nonresidential occupancy category in ANSI/ASHRAE Standard 62.1¹, Table 6-1
- b. A dwelling unit
- c. For health care, the appropriate function of space from ANSI/ASHRAE/ASHE Standard 170³ Table 7-1 (inpatient), Table 8-1 (specialized outpatient), Table 8-2 (general outpatient), and Table 9-1 (support spaces)

8.2.3.4 Potential Separation Areas. Potential separation spaces shall be evaluated as follows.

- a. In non-health care facilities, any spaces identified by the owner that could be repurposed to a designated temporary space for infected or potentially infected occupants during *IRMM* shall be evaluated.
- b. In health care facilities and spaces, the owner shall identify temporary isolation rooms during *IRMM* to be evaluated.

8.2.3.5 Equipment Inventory. The type and size of the HVAC systems that serve the occupied spaces shall be inventoried.

8.2.3.6 Multifamily Residential Buildings, Including Dorms and Hotels. In multi-unit residential buildings, including dormitories and hotels, transfer air between corridors and dwelling units, corridors and stairwells or elevator shafts, common areas and dwelling units, and utility or mechanical areas and dwelling units shall be assessed in accordance with Section B4.4.

In hotels, dormitories, and other public residential buildings, dwelling-to-dwelling transfer air shall be assessed in accordance with Section B4.4.

In pressurized corridor systems, the ventilation system assessment shall include corridor supply airflow rates sampled on at least three individual floors: above, below, and at the neutral pressure plane, along with a qualitative assessment of corridor positive pressurization relative to dwelling units.

8.2.3.7 Ventilation. Ventilation systems shall be assessed for compliance with the applicable version of the relevant indoor air quality (IAQ) standard per Section 4.1.1 and adjusted if not currently compliant. The assessment shall result in measurement of current system outdoor air delivery rates, and determination of the maximum potential outdoor airflow rates and conditions for their delivery.

8.2.3.8 Airflow Measurement. The outdoor air and supply air rate from each air handler, and the supply air rate to each *occupiable space*, that is intended to contribute to the V_{Ea_i} shall be measured, estimated, or

identified by any of the following methods:

- a. Using airflow measuring sensors that have been calibrated within the calibration interval recommended by the manufacturer
- b. Testing, adjusting, and balancing (TAB report within three years of assessment, along with site observation of supply, return, and outdoor airflow at the system)
- c. Methods in ANSI/ASHRAE Standard 111¹⁸ or equivalent as allowed by the *AHJ* to determine supply, return, and outdoor airflow.
- d. A tracer gas dilution evaluation in accordance with ASTM E741¹⁹ to determine outdoor airflow

8.2.3.9 Minimum Outdoor Airflow Requirements. The minimum outdoor airflow required for each *occupiable space* and for each air handler shall be calculated using the applicable IAQ standard.

8.2.3.10 Measured Outdoor Airflow Rates. Measured outdoor airflow rates for HVAC systems that do not comply with the applicable IAQ standard shall be identified on the issues log and be addressed in the planning and implementation phase.

8.2.3.11 Coil Condition and Capacity. Cooling or heating coils that treat outdoor air, for systems expected to condition (cool, heat, dehumidify or humidify) outdoor airflow above design rates in *IRMM*, shall be evaluated.

8.2.3.12 Energy Recovery Ventilators (ERVs). Energy recovery ventilators, if present, shall be assessed for proper airflow measurements and fan locations to determine if the ERV shall remain operational or require maintenance and upgrades to operate in *IRMM*. Assessment shall include evaluation of whether higher-than-design airflows can be achieved within the capacity of the HVAC system to maintain control of supply air conditions.

Informative Note: See Informative Appendix G, “Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems.”

8.2.3.13 Ventilation System Controls. Control capabilities shall be verified for proper operation to deliver the required quantity of outdoor air continuously throughout occupied periods.

8.2.3.14 Filtration. The following filtration system characteristics shall be documented for each system:

- a. Location of filters in the system (air path), including prefilters
- b. Size of existing filter rack
- c. Quantity and size of filters
- d. MERV-A rating of existing filters (see Section 7) for conversion to pathogen removal efficiency
- e. Fan’s design allowable pressure drops for both clean and dirty filters
- f. Evaluation of filter installation quality, including use of spacers or tape or the presence of air gaps

8.2.3.15 Exhaust. Exhaust equipment shall be confirmed to be operating as scheduled. Pressure relationships between non-health-care spaces that are intended to have a pressure differential according to design documents or an accepted TAB report shall be qualitatively assessed. Health care space pressure differential shall be quantitatively assessed. The potential for exhaust air re-entrainment into outdoor air intakes shall be assessed.

Informative Note: See Informative Appendix H, “Exhaust Re-entrainment Guide.”

8.2.3.16 Air Cleaners. All *air cleaning* systems that contribute to $V_{EAI,existing}$ shall be assessed for effectiveness and safety according to Section 7 and Normative Appendix A, and for allowable placement per Section 6.6.

8.2.3.17 Controlling Sensors. The controlling sensors on air delivery systems that will be adjusted to achieve target V_{EAI} shall be assessed for the need for calibration.

8.2.3.18 Control Strategies and Sequences of Operation. The assessment shall document the existing control strategies and sequences of operation for HVAC systems that could be affected by additional engineering controls.

8.2.3.19 Existing Engineering Controls. If any engineering controls are already in use, assess their capacity and

control according to Section 6 and Section 7 of this standard or an accepted method approved by the AHJ.

8.2.4 Existing Building Planning and Implementation. Existing building systems shall meet minimum operating requirements and be evaluated for their contribution to V_{EAI} . The need for additional engineering controls to meet the $V_{EAI,target}$ shall be determined, and potential engineering controls shall be evaluated, selected, and implemented according to the requirements of this section.

8.2.4.1 Minimum Operating Requirements. Use the information obtained during the assessment to determine if any adjustments are needed to maintain minimum operating requirements.

- a. HVAC systems for which measured outdoor air did not meet the calculated required minimum rates under the applicable IAQ standard shall be corrected in the planning and implementation phase to provide code minimum outdoor air in both normal mode and *IRMM*.
- b. Control devices or HVAC components that were deemed to be out of calibration or not functioning per the intended sequence of operations shall be corrected in the planning and implementation phase.

8.2.4.2 Determine Target ECAi. Determine the required $V_{EAI,target}$ for each *occupiable space*, where $V_{EAI,target}$ is equal to V_{EAI} as determined by Equation 5-1 using the $P_{z,IRMM}$ accepted by the owner.

8.2.4.3 Determine ECAi. The current system's $V_{EAI,existing}$ is determined by Equation 8-1, with terms as defined for Equation 6-1, for each *occupiable space* as found. The airflow measurement methods described in Section 8.2.3.8 shall be used to determine the value of each term.

$$V_{EAI,existing} = \Sigma[v_f \times (VOA_{sys} + V_{ACS,sys})] + \Sigma V_{ACS} + V_{NV} \quad (8-1)$$

8.2.4.4 Determine if Additional V_{EAI} Is Required. Equation 8-1 shall be used to determine if additional engineering controls are necessary:

$$V_{EAI,differential} = V_{EAI,target} - V_{EAI,existing} \quad (8-2)$$

If $V_{EAI,differential}$ is less than or equal to zero, then the assessment, planning, and commissioning shall be complete. No modifications are required.

If $V_{EAI,differential}$ is greater than zero, then the planning phase needs to be completed to determine the engineering controls combination to have the modified system meet or exceed the target performance.

An alternative method for determining $V_{EAI,existing}$ based on the impact of the ventilation, filtration, and filter-based air cleaners shall be the particle tracer decay methods of determining *equivalent clean airflow* for infection risk mitigation as described in Normative Appendix C.

8.2.4.5 Select Engineering Controls. Potential options to increase $V_{EAI,existing}$ shall be determined based on

- a. Physical constraints
- b. Predicted $V_{EAI,existing}$ (See Informative Appendix F, “Equivalent Clean Airflow Calculator.”)

8.2.4.6 Control Limitations. Fan speed and outdoor air control shall impact the quantity of supply, return, and outdoor air used in calculating V_{EAI} as follows:

- a. If demand-control ventilation (DCV) is deactivated in *IRMM*, the design or measured outdoor air shall be used to calculate $V_{EAI,existing}$.
- b. If DCV is activated in *IRMM*, only the minimum outdoor airflow set point to achieve the building component of the ventilation rate, plus airflow to maintain the building pressure relationship to outdoors, shall be used to calculate $V_{EAI,existing}$.
- c. If fan speed is set to constant during *IRMM*, then the measured or resulting airflows shall be used to calculate $V_{EAI,existing}$.
- d. If fan speed is allowed to modulate, then the measured minimum airflow rate shall be used to calculate $V_{EAI,existing}$.

8.2.4.7 Implement Engineering Controls. Existing systems shall be modified or supplemented with the selected engineering controls, as agreed upon by owner and operator, that provide the *IRMZ* with $V_{EAI,target}$.

- 8.2.4.8** The *BRP* shall be updated to include the existing and implemented engineering controls, their intended sequences of operation for *IRMM*, and any modifications to the existing system operations in normal mode.
- 8.2.5 Existing Building Commissioning.** All modifications to the existing system shall be verified to be working to their intent through a commissioning process that includes functional performance testing.
- 8.2.5.1** Commissioning FPTs shall be performed for any sequence of operations modified for *IRMM*. FPTs shall include the information and checks outlined in ANSI/ASHRAE Standard 230²⁰ in addition to the following:
- Test all modes of operation.
 - Normal mode: occupied and unoccupied
 - IRMM*: occupied and unoccupied
 - Test all adjustments to outdoor air control and delivery.
 - Central filtration shall include a visual check of filter bank and spacer installation by observing whether light from a source on one side of the filter bank can be seen on the other, which will make bypass paths visible.
 - Confirm air cleaner effectiveness and safety per Section 7 and Normative Appendix A.
 - Provide an issues log to the owner and contractors so that any necessary adjustments or changes can be made to ensure the systems contributing to V_{EAI} are operating as intended.
- 8.2.5.2 Systems Evaluation.** The modified systems shall be evaluated for compliance according to Section 8.2.4.3.
- 8.2.5.3 Building Readiness Plan.** All results from the previous sections shall be documented in the *BRP*.
- 8.3 New Construction and Major Renovations.** The requirements of this section apply to new buildings and systems and renovations to existing buildings and systems. Planning and implementation of engineering controls to achieve V_{EAI} in new construction and major renovations to existing buildings shall be incorporated into the design, construction, and commissioning processes of the facility for permanently installed engineering controls. Temporary *air cleaning* systems, if used, shall be identified in the *BRP*. Detailed requirements for components of the assessment, planning and implementation for new construction and major renovations are listed in Normative Appendix B.
- 8.3.1 Alterations to Existing Buildings.** Substantial alterations to existing buildings, as defined in ANSI/ASHRAE/IES Standard 90.1²¹, Section 11.1.4.1, shall follow the requirements of Section 8.3.
- 8.3.2 Owner's Project Requirements.** Assist in the development of the Owner's Project Requirements (OPR). In addition to the items noted in ANSI/ASHRAE/IES Standard 202²², Section 6, the OPR shall include potential engineering and non-engineering controls for *IRMM*.
- 8.3.3 Design Review.** The review shall determine if the expected engineering controls have been evaluated by the design team and documented in the Basis of Design, drawings, and specifications. The commissioning provider (CxP) shall perform a review of systems and assemblies in the design documents to evaluate compliance with the OPR *IRMM* systems and information and provide an issues log for the design professional to adjust the design documents to align with the OPR.
- 8.3.4 Submittals.** The CxP and designers of record shall review the infection control equipment and systems submittals concurrently. The CxP shall review the system sequences of operation submittals closely to verify that the *IRMM* operation is clearly defined with set points, enable and disable actions, and expected control devices.
- 8.3.5 Site Observations.** The CxP and designers of record shall perform site observations through the construction phase and include on the project issues log any items that do not comply with the design intent for systems to achieve the $V_{EAI,target}$.
- 8.3.6 Equipment Checklists.** The CxP shall include on the equipment checklist information about the control devices and equipment required to achieve the $V_{EAI,target}$.
- 8.3.7 Functional Performance Tests**
- 8.3.7.1** CxP shall create FPTs that are project specific and test the system's ability to transition between normal

mode to *IRMM* and verify that V_{ECAi} is achieved.

- 8.3.7.2 An alternative method for determining V_{ECAi} based on the impact of the ventilation, filtration, and filter-based air cleaners shall be the particle tracer decay methods of determining *equivalent clean airflow* for infection risk mitigation described in Normative Appendix C.
- 8.3.7.3 The designers of record shall review the FPTs to confirm the *IRMM* is being tested to meet the design intent.
- 8.3.7.4 The CxP shall identify issues that prevent the systems from operating as intended in *IRMM* and during transition from normal mode to *IRMM*. The designers of record shall work with the project team to resolve any issues.
- 8.3.8 **Training.** The CxP and designers of record shall verify that the project specification for training includes appropriate time to train the facility staff on the equipment and sequences of operation required for *IRMM*.
- 8.3.9 **Systems Manual.** The CxP shall provide the owner a systems manual that includes the equipment, functions, and sequences for HVAC system operation in *IRMM*.

Informative Note: See ASHRAE Guideline 1.4²³ for additional information available for the development of a systems manual.

- 8.3.10 **Building Readiness Plan.** The *BRP* shall be created and included as an appendix to the systems manual, Current Facility Requirements, and O&M manual.

9. OPERATIONS AND MAINTENANCE

9.1 Operations

- 9.1.1 **Building Readiness Plan (BRP).** The *BRP*, in either hard copy or electronic format, shall be maintained on site or in a centrally accessible location for the working life of the applicable ventilation system equipment or components. This plan shall be updated as necessary.
- 9.1.2 **Essential Facility Supplies for Operations.** The operator shall review the operations and maintenance (O&M) manual to understand the ongoing activities and materials required to make systems work, including spare parts. The building operator shall maintain a critical asset inventory management plan that includes storage (on site or off site) or supply chain arrangements.
- 9.1.3 **Modes.** The occupant, operator, and building owner, *AHJ*, or public health official shall determine which mode of operation shall be used for the system or space. Modes of operation shall be identified as one of the following:
 - a. Normal mode: occupied and unoccupied
 - b. *IRMM*: occupied and unoccupied
 - c. Temporary shutdown
- 9.1.4 **Operating Schedule.** Engineering controls shall be operated whenever the space is occupied in *IRMM* to provide not less than the target V_{ECAi} for all load conditions or dynamic reset conditions. The operating schedule shall be controlled by one or more of the following:
 - a. Time of day scheduling shall be inclusive of all times that spaces are occupied, including by support staff and vendors.
 - b. Occupancy sensors shall be used in accordance with ANSI/ASHRAE Standard 62.1¹, Section 6.2.6.1.4. Ventilation that is switched to an occupied standby mode if the HVAC system is in normal mode shall be turned on if occupancy is detected. The ventilation systems shall turn on if occupancy is detected during unoccupied hours.
 - c. During *IRMM*, intermittent ventilation (such as fans that supply primary air cycling ON/OFF with heating/cooling) shall not be permitted to count towards the V_{ECAi} target when the space is occupied.
 - d. Demand-control ventilation (DCV) shall operate as noted in the *BRP*.
- 9.1.5 **Flush Between Occupied Periods.** For systems achieving V_{ECAi} targets, flushing shall not be required between occupied periods.

- 9.1.6 Occupant Count During IRMM.** If the occupant count exceeds $P_{z,IRMM}$, during *IRMM*, V_{ECAi} calculations shall be updated to determine if changes to engineering controls and non-engineering controls must be implemented to achieve the revised $V_{ECAi,target}$.
- 9.1.7 Operation at Varying Fan Speeds.** Operator shall confirm that systems with variable speed fan control aligns with the *BRP* and resulting $V_{ECAi,existing}$ during *IRMM*.
- 9.1.8 Temperature and Humidity.** Maintain temperature and relative humidity set points during all occupied modes, as indicated in design documents.
- 9.1.9 Air Distribution.** Operator shall confirm that air distribution used in the spaces aligns with the clean air distribution category, and with the *BRP* as noted, per Table 6-1. If any form of variable-air-volume, multispeed constant-air volume, economizer, or demand-controlled ventilation system is used for energy conservation, it shall not compromise clean air distribution pressure balancing and control. Pressure relief, return, and exhaust systems shall adjust accordingly during normal mode and *IRMM*.
- 9.1.10 Separation Area.** If the building has a designated separation area for potentially infected or infected individuals, this temporary area shall remain separated by doors and kept under negative pressure, relative to all adjoining rooms, whenever a potentially infected or infected individual is present.
- 9.1.11 Operator Training.** Operators shall receive training on the following topics:
- a. Ventilation requirements during normal mode and *IRMM*
 - b. Requirements for the facility, spaces, equipment, and systems as noted in the *BRP*
- 9.1.12 Occupant Communication.** Information about the current and possible operating modes and building occupancy limits when in *IRMM* shall be posted in a public location near the entrance to the building or space. Equipment used to achieve V_{ECAi} that can be adjusted by the occupants shall have signage indicating required settings. The *BRP*, which shall include mode, intended target V_{ECAi} by system, current operating schedules, and any occupancy limits, shall be made available to all occupants of the building.

9.2 Maintenance

- 9.2.1 Maintenance.** Systems shall be maintained in accordance with the requirements of this section while the systems are operating in *IRMM*.
- 9.2.2 Tasks and Frequency.** Maintenance tasks and frequencies for all occupancies and system types shall follow ASHRAE/ACCA Standard 180²⁴ as well as any system-specific requirements listed below. Upon transition to *IRMM*, tasks shall be performed that have not been performed within the intervals indicated in Table 9-1 and Table 9-2.
- 9.2.2.1 Ventilation Equipment.** Maintenance tasks and frequencies for all ventilation equipment shall follow Table 9-1. Exceptions for small systems are not applicable to this standard.

Informative Note: These tasks and frequencies are based on ANSI/ASHRAE Standard 62.1¹, Table 8-1.

9.2.2.2 Air Cleaning Equipment

- a. **In Use.** Maintenance tasks and frequencies for all *air cleaning* equipment shall follow the manufacturer's instructions and any tasks listed in Table 9-2 while in use.
 - b. **Testing While Not in Use.** All *IRMM* engineering controls that are disabled in normal mode shall be tested semiannually.
- 9.2.2.3 Test Areas in Compliance with Normative Appendix C**
- 9.2.2.3.1** Every 12 months, testing shall be completed for a new set of randomly selected spaces from the previous test locations.
 - 9.2.2.4 Control Systems.** Remote or off-site access to building control systems, if present, shall be tested for successful control on a quarterly basis.
 - 9.2.2.4.1** Control system transition between normal mode and *IRMM* shall be tested on a semiannual basis.
- 9.2.3 Cleaning.** Review and document the custodial program for the facility. Pay particular attention to roles and responsibilities for staff and external contractors related to HVAC equipment and other equipment used to comply with this standard. (See ISSA 0415²⁵, Section 3.)

Table 9-1 Minimum Maintenance Activity and Frequency for Ventilation System Equipment and Associated Components

Inspection/Maintenance Task	IRMM Maintenance Interval
Check pressure drop and scheduled replacement date of filters and <i>air cleaning</i> devices. Confirm that pressure drop readings do not exceed the maximum pressure drop of the filter or the maximum allowable for the fan based on the static pressure calculations. Clean or replace as necessary to ensure proper operation.	Quarterly or when replaced, whichever is more frequent
Check P-traps in premise plumbing and floor drains located in plenums or rooms that serve as air plenums. Prime as needed to ensure proper operation.	Monthly
Visually inspect outdoor air intake louvers, bird screens, natural ventilation openings, and adjacent areas for cleanliness and integrity; clean as needed. Remove all visible debris or visible biological material observed and repair visible damage to louvers or screens if such damage impairs the provision of outdoor air.	Monthly
Verify the operation of natural ventilation manual and automatic opening controls for proper operation; repair or replace as necessary.	Monthly
Verify the operation of the outdoor air ventilation system and any dynamic minimum outdoor air controls; repair or replace as necessary.	Quarterly
Check air filter fit and housing seal integrity. Correct as needed.	Annually or when replaced, whichever is more frequent
Check for proper damper operation. Clean, lubricate, repair, replace, or adjust as needed to ensure proper operation.	Quarterly
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, flow stations at ventilation zones, and those used for demand-controlled ventilation, including CO₂ sensors, and handheld 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 ²⁶ or ASHRAE Standard 111 ¹⁸.	As recommended by the sensor manufacturer, but not less frequently than every three years.

Table 9-1 Minimum Maintenance Activity and Frequency for Ventilation System Equipment and Associated Components

Inspection/Maintenance Task	IRMM Maintenance Interval
Verify the total quantity of outdoor air delivered by air handlers set to minimum outdoor air mode. If measured minimum airflow rates are less than the design minimum rate documented in the O&M manual, $\pm 10\%$ balancing tolerance, (a) confirm the measured rate does not conform with the provisions of this standard and (b) adjust or modify the air handler components to correct the airflow deficiency. Ventilation systems shall be balanced in accordance with ASHRAE Standard 111¹⁸ or its equivalent, at least to the extent necessary to verify conformance with the total outdoor airflow and space supply airflow requirements of this standard. (Note: No systems are exempt from this requirement based on size.)	Every three years

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 <i>BRP</i>. Confirm that the air cleaner is operating at the speed or setting assumed in the $V_{E C A i}$ calculation. Maintain systems and equipment and verify performance per manufacturer's instructions. Visually inspect intake for debris and clean as necessary.	Monthly
Germicidal ultraviolet (GUV)	Maintain systems and verify performance and safety per manufacturer's instructions and in accordance with ANSI/IES RP-44-21¹⁴ and ANSI/IES RP-27.1-22¹⁶ or equivalent. Adjust, clean, and replace equipment as needed.	Assess quarterly or per manufacturer's recommended interval
All <i>air cleaning</i> systems and equipment (including in-room, in-duct, and GUV 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 $V_{E C A i}$ 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

10. DWELLING UNITS—ADDITIONAL REQUIREMENTS

10.1 Dwelling units shall be treated as a single *IRMZ*, except as noted in Section 10.5.

10.2 General Requirements

10.2.1 All toilets shall be provided with lids.

10.2.2 All plumbing traps shall be filled with water.

10.2.3 Fans used to meet the requirements of this standard that are connected to ductwork shall have their flows measured in accordance with either Section 4.3 or Section 5.4 of ANSI/ASHRAE Standard 62.2² or equivalent.

10.3 Building Readiness Plan (BRP). A *BRP* shall be created to describe the engineering and non-engineering controls that will be used to achieve its total target *equivalent clean airflow* for infection control (V_{ECAi}) during *IRMM*. The *BRP* shall be included in a section of the operations and maintenance manual required by ANSI/ASHRAE Standard 62.2², Section 8. The *BRP* shall require that local exhaust ventilation be operated in bathrooms and toilets when in use and shall indicate that toilet lids are to be closed when flushing.

10.4 Multifamily Dwellings

Buildings with forced-air HVAC systems supplying air that is returned through ductwork from more than one dwelling unit shall have at least MERV-13A filtration or ePM1 of 50% per Table 7-1 filtration or equivalent. In existing buildings that do not meet this requirement, the HVAC systems shall be blocked off, and portable HVAC and air filtration/*air cleaning* units shall be provided.

10.5 Separation Areas

When a dwelling unit has infected or vulnerable occupants, a separate fully-enclosed space shall be used as a separation area and will be treated as a separate *IRMZ*. A single space may be used to comply with either Section 10.5.1 or Section 10.5.2, provided operation and any reconfiguration is described in the *BRP*. The *BRP* shall specify what protections caregivers shall take when entering a separation area. When the separation area does not have toilet or bathroom facilities, the *BRP* shall document how occupants of that area will access toilet or bathroom facilities outside the area while minimizing infection risk.

Exception to Section 10.5: Dwelling units having a single habitable zone combining all sleeping and living functions shall be treated as a single *IRMZ* and have a required *equivalent clean airflow* rate V_{ECAi} per Equation 5-1 using $ECAi$ of 100 cfm (50 L/s) per person.

10.5.1 *IRMZ* for Infected Occupants. The *IRMZ* for infected occupants shall meet either Section 10.5.1.1 or Section 10.5.1.2.

10.5.1.1 Unsealed transfer grilles or jump ducts shall have a damper that operates during *IRMM* to prevent flow from the *IRMZ* for *infected occupants* to other parts of the dwelling unit. An exhaust ventilation system capable of a minimum of 200 cfm (100 L/s), shall be operated. A fan installed in a window or other opening shall be permitted. Any supply registers and return grilles in the room that are part of the dwelling's central conditioning systems shall be sealed, with temporary space conditioning provided as needed.

10.5.1.2 The *IRMZ* for *infected occupants* shall contain an exhaust ventilation system that can maintain a measured negative pressure of 0.02 in. H₂O (5 Pa) with respect to the rest of the dwelling unit.

10.5.2 *IRMZ* for Vulnerable Occupants. The *IRMZ* for vulnerable occupants shall meet either Section 10.5.2.1 or Section 10.5.2.2. Air that is mechanically recirculated from other parts of the dwelling unit into the *IRMZ* for *vulnerable occupants*, such as via supply registers, shall meet the requirements of Section 10.4.

Exception to Section 10.5.2: No *IRMZ* for vulnerable occupants is required when the dwelling unit *equivalent clean airflow* meets or exceeds required *equivalent clean airflow* V_{ECAi} per Equation 5-1 using $ECAi$ of 100 cfm (50 L/s) per person. For attached dwelling units, exhaust ventilation shall not exceed V_{tot} from ANSI/ASHRAE Standard 62.2², Section 4.1.1, or the dwelling unit ventilation rate if complying with another equivalent standard.

10.5.2.1 Unsealed transfer grilles or jump ducts shall have a damper that operates during *IRMM* to prevent flow to the *IRMZ* for *vulnerable occupants* from other parts of the dwelling unit. A supply ventilation system capable of a minimum of 200 cfm (100 L/s) shall be operated to supply *equivalent clean air* to the *IRMZ* for *vulnerable occupants*. A fan installed in a window or other opening shall be permitted.

10.5.2.2 The *IRMZ* for *vulnerable occupants* shall contain a supply system that can maintain a measured positive pressure of 0.02 in. H₂O (5 Pa) with respect to other parts of the dwelling unit.

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(This appendix is part of this standard. It contains requirements necessary for conformance to the standard.)

NORMATIVE APPENDIX A—DETERMINING AIR CLEANING SYSTEM EFFECTIVENESS AND SAFETY

A1 GENERAL

Test reports for effectiveness and safety shall be publicly available for *air cleaning* systems applied under the requirements of this standard.

A1.1 Parity. Testing for effectiveness and safety shall be performed using identical operating conditions of the *air cleaning* system equipment, but the testing shall be performed separately. The environmental and airflow conditions (external to the *air cleaning* system) in the effectiveness and safety test environments shall be equivalent. The environmental, airflow, installation and operating conditions used in testing shall correspond to the intended application and use of the *air cleaning* system equipment for contributing ECA_i under this standard.

A1.2 Testing Laboratories. Testing shall be performed by independent laboratories that meet OSHA Nationally Recognized Testing Laboratory requirements²⁸ or other equivalent national bodies. Testing for effectiveness and safety may be performed by a single laboratory or separate laboratories. All testing laboratories shall comply with the requirements of ISO/IEC 17025²⁹.

A1.3 Air Cleaner System Installation. *Air cleaning* system equipment shall be installed for effectiveness and safety testing following the manufacturer's published specifications and in a manner that minimizes impacts on other testing procedures. The independent test laboratory shall certify that the installation meets these conditions or describe any potential impacts in the testing report.

A1.4 Quality Assurance and Quality Control Measures. To ensure the quality of testing, the following measures shall be taken:

- a. All equipment used in testing shall be calibrated per manufacturer instructions.
- b. All equipment and surfaces shall be decontaminated between tests as necessary to eliminate cross-contamination between tests.
- c. The test equipment shall be placed within the chamber prior to testing, except for control tests with an induct *air cleaning* system where having the system in place would contribute to aerosol reduction.
- d. Samples shall be collected, handled, and analyzed in the same manner for all test iterations.
- e. Background samples for each sampling target during testing (particle, biological, or chemical analyte) shall be collected prior to each test.

A1.5 Reporting Requirements. The independent testing laboratory shall prepare a test report that contains sufficient information and detail to ensure repeatability of the tests and that, at a minimum, contains the following:

- a. The name, address, and contact information of the laboratory performing the test, the names of test operators performing each test, and the names and affiliations of the authors, contributors, and reviewers of the report
- b. The name, address, and contact information of the party requesting the test
- c. A description of the *air cleaning* system being tested, including model number, size, and features
- d. The manufacturer-recommended operational and environmental conditions of the *air cleaning* system equipment; a description of how the *air cleaning* system equipment is installed in the test chamber
- e. A certification that the *air cleaning* equipment has been installed to minimize impacts on other equipment or testing methods, or a description of any potential interferences of the *air cleaning* equipment on testing processes
- f. A description of the test chamber, including its dimensions, a description of its surfaces, and the location and orientation of equipment installed within (including *air cleaning* system, mixing, nebulization, and sampling equipment)
- g. The date and time of the test

- h. The make, model, minimum resolution, minimum limit of detection and quantitation, accuracy, precision, and date of last calibration for each piece of measuring equipment
- i. A log of the environmental and airflow conditions of the test environment throughout the duration of each test
- j. A log of the operating conditions of the tested equipment throughout the duration of each test
- k. Quantitative sampling results from all samples collected during testing, including background samples
- l. A quantification of uncertainty, based on replicate testing and methods detection limits

A1.6 Testing Certification Requirements. The independent laboratory shall prepare, review, and approve the test report.

A2 EFFECTIVENESS

A2.1 Air Cleaning System Effectiveness. Effectiveness testing for all *air cleaning* systems shall be performed following a consensus standard and in accordance with the additional requirements listed in this section. Where multiple test methods are applicable, the manufacturer or certifying body shall select the most appropriate test method to rate performance in a manner that is aligned with the intended use and operation of the *air cleaning* system.

A2.1.1 Bioaerosol Effectiveness Testing Requirements. Effectiveness testing conducted using a bioaerosol challenge are subjected to the additional requirements stated in this section. The following requirements shall supersede the requirements stated in the respective referenced consensus standards.

A2.1.1.1 Biosafety Requirements. All biological testing and procedures shall be conducted in accordance with the current version of the CDC/NIH *Biosafety in Microbiological and Biomedical Laboratories* ³⁰.

A2.1.1.2 Test Microorganism and Microbiological Procedures. All effectiveness testing using microorganisms shall be performed with the nonenveloped bacteriophage MS2 (host *Escherichia coli*). The test microorganism shall be suspended in an artificial saliva prepared using the recipe in Heimbuch et al. ³¹ (Table A-1) and aerosolized to produce discrete particles. Addition of an antifoaming agent to the microbial suspension is permitted. Bioaerosol samples for chamber tests shall be collected between 48 and 50 in. (123 and 127 cm) above the floor and >2 ft (0.6 m) from walls or equipment. Samples shall be collected using impingers, impactors, or other sampling methods as determined by the testing laboratory. The test microorganism samples shall be collected, handled, and analyzed in the same manner for all test iterations. Each collected impinger sample shall be plated in triplicate.

A2.1.1.3 Test Controls and Replicates. For effectiveness testing using a biological challenge agent, a minimum of three acceptable test replicates for each test condition (*air cleaning* system OFF and *air cleaning* system ON) shall be performed, for a minimum of six total acceptable tests per *air cleaning* system. Each test replicate shall consist of a separate sequence of aerosolization, sampling, and chamber or duct reset procedures.

A2.1.1.4 Bioaerosol Reduction Effectiveness Calculations. The effectiveness calculations resulting from all bioaerosol testing shall

- a. Account for background reduction of the test microorganism
- b. Compare averages of time-matched sample recoveries from test replicates with the *air cleaning* system off to the averages of the replicates with the *air cleaning* system on
- c. Shall not use samples collected with microorganism recoveries lower than the limit of detection in effectiveness calculations

A2.1.1.5 Biological Effectiveness Testing Reporting Requirements. In addition to the reporting requirements in Section A1.5, the independent testing laboratory shall include the following information in the report from all effectiveness testing utilizing bioaerosols:

- a. A description of the aerosolization equipment, procedures (including the composition of the microbial suspension and concentrations of its constituents), and location(s) within the test chamber

- b. A description of the sampling equipment and procedures, including the media used for sampling, sampling locations, sampling times, and the air volume extracted for each sample
- c. A description of the microbiological assay and enumeration methods, including the limit of detection
- d. The results from each test replicate, including propagated error for each sample collected based on replicate sampling and plating to demonstrate reproducibility and uncertainty
- e. The calculations for effectiveness, including all values and equations used

Table A-1 Artificial Saliva Recipe

Reagent	Amount
MgCl ₂ ·6H ₂ O	0.04 g
CaCl ₂ ·H ₂ O	0.13 g
NaHCO ₃	0.42 g
0.2 M KH ₂ PO ₄	7.7 mL
0.2 M K ₂ HPO ₄	12.3 mL
NH ₄ Cl	0.11 g
KSCN	0.19 g
(NH ₂) ₂ CO	0.12 g
NaCl	0.88 g
KCl	1.04 g
Mucin	3.0 g
Distilled Water	Fill to 1000 mL
pH	7

A2.2 Chamber Testing with a Duct. For *air cleaning* systems with an effectiveness reported as an *equivalent clean airflow* delivery rate that require test chamber air to recirculate through a side duct or test duct within the test chamber, *air cleaning* system effectiveness shall be evaluated with a modified chamber to include the duct. The test duct shall maintain the same temperature and humidity as the test chamber throughout testing. Only the *air cleaning* system being tested shall be mounted in the recirculating duct. Airflow through the duct shall provide the most challenging (i.e., worst-case) test condition for the *air cleaning* system being tested, as determined by the laboratory from the range of operating conditions advertised by the system manufacturer.

A3 SAFETY

A3.1 Required Tests. *Air cleaning* system safety shall be tested as required by this section.

Exception to A3.1: *Fibrous filters* placed in an airstream or *air cleaning* systems using only *fibrous filters* (and no other *air cleaning* mechanism) and only powered air moving equipment (inclusive of its controls) do not have additional safety testing requirements.

A3.1.1 Chemical Analytes Released by Air Cleaning Systems or Resulting from Chemical Reactions in the Air. Air cleaners shall be tested for analytes according to ASTM D8625⁴⁹. All requirements in ASTM D8625 shall be required, except Tests 3 and 4 (and associated processes and analyses).

A3.1.1.1 For *air cleaning* systems that require test chamber air to recirculate through a side duct or test duct within the test chamber, the chamber meeting all other requirements of ASTM D8625⁴⁹ shall be modified to include the duct. The test duct shall maintain the same temperature and humidity as the test chamber throughout testing. Only the *air cleaning* system being tested shall be mounted in the recirculating duct.

A3.1.1.2 For each analyte, Table A-2 lists the applicable ASTM D8625 measurement and the acceptable limit for application. *Air cleaning* systems not meeting the acceptable requirements shall not be used under the provisions of this standard.

Table A-2 Required Analytes for Safety Testing

Analyte of Concern	Abbreviation	Measurement	Acceptable Limit
Formaldehyde	HCHO	Formaldehyde generation rate, $G_{\text{formaldehyde}}$	$G_{\text{formaldehyde}}$ less than 50 $\mu\text{g/h}$
Ozone	O ₃	Ozone generation rate, G_{ozone}	G_{ozone} less than 400 $\mu\text{g/h}$
Increase in particulate matter volume concentration ($\mu\text{g}/\text{cm}^3$)	Particles greater than 20 nm	Maximum particle mass increase, $V \cdot C_{\text{max}}$ <i>C_{max} is from Equation 2 in Section 9.1.2 of ASTM D8625. V is the volume of the test chamber (m^3)</i>	$V \cdot C_{\text{max}}$ less than 6 μg

Exception to A3.1.1.2: *Air cleaning* systems test to meet the UL 2998 ⁴⁹ zero ozone emissions environmental claim are not required to be tested for ozone generation per ASTM D8625 ⁴⁹. For devices meeting UL 2998 ⁴⁹, G_{ozone} is assumed to be 400 $\mu\text{g/h}$.

A3.1.1.3 Application Requirements. Application of *air cleaning* systems located within a common *IRMZ* shall meet minimum volume requirements to ensure analyte concentrations do not exceed acceptable levels when all devices are operated. For each analyte listed in Table A-3, the total generation rate shall be calculated using Equation A-1, and the application minimum volume, $V_{\text{min},a}$, shall be calculated using Equation A-2. Table A-3 lists the analyte specific parameters required in Equation A-2. The minimum volume for the application, V_{min} , shall be the lowest of analyte specific minimum volumes calculated. Applications in which the volume of the IMRZ is less than V_{min} shall not be used under the provisions of this standard.

$$G_{\text{tot},a} = \sum_{i=1}^n G_{a,i} \quad (\text{A-1})$$

$$V_{\text{min},a} = \frac{G_{\text{tot},a}}{(\lambda + L_a) \Delta C_a} \quad (\text{A-2})$$

where

- a = analyte of interest
- $G_{\text{tot},a}$ = total generation rate of analyte a from all devices in the zone, $\mu\text{g/h}$
- $V_{\text{min},a}$ = minimum application volume for analyte a , m^3
- λ = application minimum outdoor air change rate (ACH)
- L_a = Deposition rate for analyte a , hr^{-1} (see Table A-3)
- ΔC_a = maximum acceptable concentration increase for analyte, $\mu\text{g}/\text{m}^3$ (see Table A-3)

Table A-3 Analyte Specific Parameters for Minimum Volume Calculations

Analyte of Concern	Deposition Rate, L_a	Maximum Acceptable Concentration Increase, ΔC_a
Formaldehyde	0 hr^{-1}	3 $\mu\text{g}/\text{m}^3$ (2.4 ppb) ^a
Ozone	3 hr^{-1}	10 $\mu\text{g}/\text{m}^3$ (5 ppb) ^a

- a. Conversion from $\mu\text{g}/\text{m}^3$ to ppb at 20°C (68°F) and 1 atm.

A3.2 Safety Testing Reporting Requirements. In addition to the general reporting requirements listed in Section A1.5 and ASTM D8625⁴⁹, Section 10, the independent testing laboratory shall include the following information in the test report:

- a. A concentration log of any direct products intentionally introduced into the air by the air cleaning system during safety testing
- b. Clear indication of whether a tested *air cleaning* system exceeded targets outlined in Table A-2 during testing.

(This appendix is part of this standard. It contains requirements necessary for conformance to the standard.)

NORMATIVE APPENDIX B—ASSESSMENT, PLANNING, AND IMPLEMENTATION

B1 OCCUPIED SPACE INVENTORY

In addition to the space category, the following items shall be documented for each space:

- a. Geometry: floor area, ceiling height, and any partial-height walls within the space
- b. Number of occupants indicated in the HVAC design, current occupant count, and occupants planned to be allowed during *IRMM* per Section 5.1.1
- c. Space use, including categorization under the applicable IAQ standard and Table 5-1
- d. Occupancy schedule
- e. Space conditions that could impact the feasibility of in-room *air cleaning* devices
- f. Locations, sizes, and control method for any openings to the outdoors
- g. Locations and types of airflow inlets and outlets

B2 EQUIPMENT INVENTORY

The inventory of air delivery systems shall include

- a. Space the equipment serves
- b. Type of air delivery systems: variable or constant volume, single or multiple zones, 100% outdoor air or recirculating
- c. Cooling source
- d. Heating source
- e. Type of ventilation (mechanical, natural, or hybrid) and how outdoor air is delivered to the space (system, path, openings)
- f. Outdoor airflow measurement devices
- g. Ventilation airflow control method, and, if variable, under what conditions
- h. Associated exhaust fans
- i. Method of control, whether manual, local (thermostat), or central (building automation system). The following information shall be identified if present:
 1. Controlling set points
 2. Controlling sensor types and locations
 3. Schedules
 4. Setbacks
 5. Trend reports and alarm logs
 6. Life safety interfaces with HVAC
 7. Access control interlocks, interfaces with HVAC
 8. Smoke control system interfaces with HVAC

B3 POTENTIAL RESPIRATORY SEPARATION AREA

The assessment for a repurposed space shall include evaluation of

- a. Physical separation from the rest of the building by at least one door
- b. Whether systems exist to create negative pressure relative to adjoining rooms
- c. A path of egress for potentially infected or infected individuals

Informative Note: A building may have multiple designated isolation areas (e.g., a healthcare facility), and occupants may stay in these areas indefinitely if allowed by the building owner's response plan.

B4 VENTILATION

B4.1 Minimum Outdoor Airflow Requirements. Mechanical ventilation in nonresidential spaces shall use either of the following procedures to determine compliance for the current space use and occupancy:

- a. Ventilation Rate Procedure (prescriptive). Determine outdoor air systems compliance per ANSI/ASHRAE Standard 62.1¹, Section 6.2.
- b. Indoor Air Quality Procedure (performance). Determine outdoor air and *air cleaning* systems compliance per ANSI/ASHRAE Standard 62.1¹, Section 6.3.
- c. Natural ventilation in nonresidential spaces shall use ANSI/ASHRAE Standard 62.1¹, Section 6.4, to determine the required area of openings. Assessing engineers shall determine the outdoor conditions when natural ventilation will provide expected airflow and when mechanical ventilation will be used.
- d. Residential spaces shall use ANSI/ASHRAE Standard 62.2², Section 4 or Normative Appendix A, to determine the required ventilation rates.
- e. Health care spaces shall use ANSI/ASHRAE/IES Standard 170³, Sections 7 through 9, to determine the required ventilation rates.

B4.2 Coil Condition and Capacity. The coils shall be evaluated as follows:

- a. Assess coil capacity under the following conditions:
 1. Design cooling day
 2. Design heating day
- b. Identify the last maintenance cleaning of the coils per ANSI/ASHRAE/ACCA Standard 180²⁴. Attach any coil cleaning reports to the *BRP*.
- c. Confirm that the coil valves are operational and modulate as intended by the controlling signal.
- d. Record the condensate line size.
- e. Assess freeze protection controls and capacity.

B4.3 Ventilation System Controls. Ventilation systems controls shall be evaluated to check the following:

- a. Control damper operation and control sequence
- b. Fan speed adjustment capability, variable air volume, or constant air volume
- c. Fan cycling
- d. Demand-controlled ventilation (DCV) strategies (temperature, carbon dioxide, timed, or occupancy sensing) resulting in variable total air delivery

B4.4 Pressurization. Building and space pressurization shall be assessed, including:

- a. Doors that will not close
- b. Perceivable noise at entrance doors and between adjacent spaces
- c. Reverse of the expected pressure relationship between spaces

B5 CONTROLLING SENSORS

Evaluate the controlling sensors or devices on air delivery systems that will be adjusted to achieve target V_{ECAi} by checking the calibration of the following:

- a. Air temperatures
- b. Air pressures
- c. Air relative humidity
- d. Airflow rate
- e. Freeze protection
- f. CO₂

B6 CONTROL STRATEGIES AND SEQUENCES OF OPERATION

Assess the control strategies and sequences of operation that may be adjusted to implement engineering controls, including:

- a. Scheduling and temperature setbacks

- b. Fan speed control, min and max
- c. Outdoor air control
- d. Minimum and maximum air quantities
- e. Outdoor air control methods
- f. Building and space pressure controls
- g. Economizer sequencing
- h. Existing *IRMM* sequences
- i. Demand-controlled ventilation
- j. Humidification control set points and upper limits
- k. Dehumidification control and limits
- l. Temperature, high and low, cutoffs for ventilation delivery
- m. Cooling and heating availability
- n. Energy recovery ventilation (ERV) operation
- o. *Air cleaning* equipment operation
 - 1. In HVAC systems
 - 2. In room

B7 OUTDOOR AIR INCREASE VERIFICATION

Increases of outdoor air ventilation shall be verified by one of the following methods:

- a. An air balance report of the outdoor air
- b. As measured by an outdoor air measuring station with verified calibration

B8 HEALTH CARE

B8.1 Capture Test. Capture devices placed in rooms in spaces expected to be occupied by infected people shall be verified by a capture test and compared against the design assumption of capture effectiveness to prove that air cleaner performance complies with expected performance.

B8.2 Room Pressure Test. Room pressurizations used for containment shall be verified by one of the following methods:

- a. A pressure relationship test and compared to the design assumptions of pressure relationship
- b. A containment test, wherein a negative-pressure single door shall achieve not less than 97% barrier effectiveness³⁷.

B9 COMMISSIONING FUNCTIONAL PERFORMANCE TESTS (FPTs)

Test all adjustments to outdoor air control and delivery, including:

- a. Ventilation alterations to DCV
- b. Ventilation control if there is an increase in outdoor air
- c. Ventilation control for expanded economizer mode
- d. Building pressure sequences

B10 NEW CONSTRUCTION AND MAJOR RENOVATION

B10.1 Owner's Project Requirements (OPR). The OPR shall include:

- a. $V_{E,CAI}$ for the HVAC systems to achieve when in *IRMM*
- b. Occupancy anticipated during *IRMM*
- c. Filtration MERV ratings
- d. Requirements for areas designated as separation areas for infected or potentially infected occupants in *IRMM*
- e. Desired *air cleaning* engineering controls for the HVAC systems and spaces

B10.2 Design Documentation. The following documentation is required to be created by the design team.

- B10.2.1** The design team shall create a Basis of Design that includes
- Analysis and identified engineering controls to achieve the target *equivalent clean airflow* for infection control (***Informative Note:*** Use the V_{ECAi} calculator described in Informative Appendix F to assist in engineering controls analysis.)
 - A complete sequence of operation and control diagrams for system operation in *IRMM*
 - A table of the normal mode and *IRMM* objectives to summarize the engineering controls applied to this facility
 - Determination of outdoor air systems compliance per applicable standard or code, as required by the local *AHJ*
- B10.2.2** The commissioning provider shall review the design team calculations indicating how the systems and equipment are achieving the target *equivalent clean airflow*.

(This appendix is part of this standard. It contains requirements necessary for conformance to the standard.)

NORMATIVE APPENDIX C—IN-PLACE TEST METHOD FOR DETERMINING THE EQUIVALENT CLEAN AIRFLOW FOR INFECTION RISK MITIGATION (V_{ECAi}) OF A SINGLE OCCUPIED SPACE BY MEANS OF TRACER AEROSOL DECAY

This appendix presents an in-place method³⁸ of testing the *equivalent clean airflow* rate for infection risk mitigation (ECAi) for a single occupied space as induced by all physical removal mechanisms (i.e., those that remove particles from the air), including passive and mechanical ventilation, filtration, and deposition. The method does not measure contributions of pathogen inactivation techniques that do not remove particles, such as GUV. The technique is based on the measurement of the decay rate of tracer particles.^{39–45} ECAi metrics are calculated according to the decay rate of the tracer particles⁴⁰ during their removal from the space, and compared to the target V_{ECAi} for the space. This in-place test provides a pass/fail result for the target volumetric airflow as derived from the ECAi in Table 5-1 and the occupancy category and quantity, and a value for $V_{ECAi,existing}$ for a specific space.

C1 EQUIPMENT

- a. **Aerosol generator.** Device used to disperse aerosol particles into the air from a liquid solution that shall generate particles in the E_1 , E_2 , and E_3 size ranges as defined in ANSI/ASHRAE Standard 52.2⁵.
- b. **Aerosol detector (AD).** Instrument that measures tracer aerosol concentrations. Aerosol detectors shall have demonstrated accuracy within $\pm 10\%$ of the reading of an ISO qualified reference aerosol detector throughout the full measurement range of the instrument⁴². Other aerosol detectors (e.g., instantaneous biological analyzers and collectors (IBACs), for fluorescent-tagged polystyrene beads; qPCR; and DNA sequencers, for DNA-tagged particles) shall have demonstrated accuracy, calibrated to within $\pm 10\%$ of a standard reference.
- c. **Tracer Particles.** Particles are released in the air by an aerosol generator to measure aerosol removal within an indoor environment. Qualified tracer particles include liquid aerosols, such as NaCl^{38,41,43,44,45}, DNA-tagged particles^{40,45,47}, fluorescent-tagged polystyrene latex beads⁴⁵, and smoke/other particulate-based tracers³⁷. When choosing tracer particles, consideration shall be given to the toxicity or sensitizing impacts of the tracer particles used, whether the space is occupied during testing, and the response time of the detector.

C2 PREPARATION

- a. **Sampling.** Testing shall include at least the number of test areas determined as the larger of:
 - 10% of the total occupied area in ft^2 (m^2), divided by 900 ft^2 (83.6 m^2), rounded up to the nearest whole number
 - 10% of the total number of distinct occupied space counts, rounded up to the nearest whole number.

A minimum of two test areas shall be required if the occupied area is greater than 900 ft^2 (83.6 m^2). These test areas shall be randomly selected in the occupancy category (as indicated in Table 5-1) that are representative of the primary use of the building.

In a mixed-use building, test areas shall be distributed proportionately across occupancy categories, such that the percentage of the test points allocated to each occupancy category is equal to the percentage that each occupancy category represents of the total number of categories. In a large open space with multiple test areas, any failures require that the entire space and its HVAC systems be evaluated.

- b. All equipment shall be calibrated within one year and in accordance with the manufacturer's specifications.
- c. Select the test space(s). In rooms larger than 900 ft^2 (83.6 m^2), multiple test areas shall be used to cover the space.
- d. Testing shall be performed under steady-state conditions for a given ventilation and filtration setup, with HVAC system and air cleaner settings held constant for the duration of the test.
- e. Movement in the test area shall be restricted for the duration of the test.
- f. There shall be no aerosol-generating sources, whether natural or mechanical (other than those identified in Section C1.a), active in the test space(s).

- g. Measure and record the volume of the space.
- h. Place the aerosol generator at the center of the test area. There must be at least four aerosol detectors with at least one device placed in the center of each quadrant as per Figure C-1. (**Informative Note:** For spaces smaller than 15 ft. $\times$ 15 ft. [4.5 m $\times$ 4.5 m], the quadrants can be smaller). The aerosol generator and aerosol detectors shall be placed at the same height within the space, 3 to 72 in. (0.08 to 1.8 m) above the floor.

C3 TEST EXECUTION

Particle counts shall be collected for each aerosol detector, in E_1 , E_2 , and E_3 size ranges for the duration of background, release, and settling periods, as represented in Figure C-2:

- a. **Background period.** The period beginning five minutes prior to the aerosol generator being turned on. $PC_{Background,En}$ is defined as the average particle count in this period. If the aerosol tracer is not found in the ambient air, background levels do not need to be assessed.
- b. **Release period.** The period beginning when the aerosol generator is turned on and ending when the aerosol generator is turned off. The aerosol generator shall operate until particle counts are at least three times the background particle count ($PC_{SDC} \geq 3 \times \text{background}$) at the time the decay period begins (t_{SDC}) for all locations and for all three particle size ranges (E_1 , E_2 , E_3). The time at which the generator is turned off is $t = 0$ minutes. See Figure C-2.
- c. **Settling period.** The six-minute period beginning when the aerosol generator is turned off.
- d. **Decay period.** The period beginning when the settling period ends and ending when either $t_{test,90\%}$ (calculated using Equation C-3) is reached or when 90% particle count reduction (which is 10% of $[PC_{SDC} - PC_{Background,En}]$) is reached, whichever comes first.
- e. **Minimum Number of Data Points during Decay:** 5. For sensors that sum all particles under the curve during decay and thus provide a direct measurement of $AUC_{ADn,En}^{tot}$, Sections C4.3 through C4.5 are not needed.

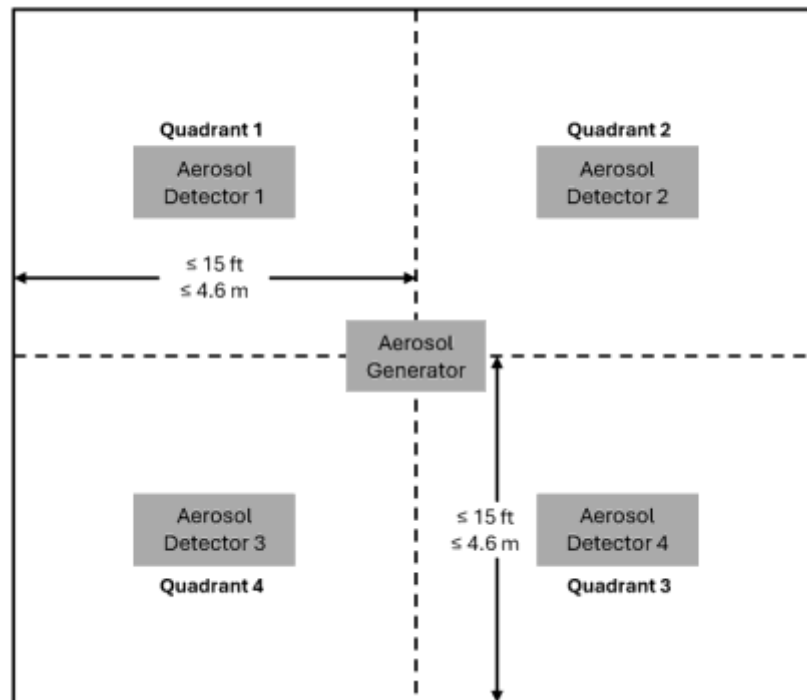


Figure C-1 Equipment configuration for determining ECAi of an occupied space.

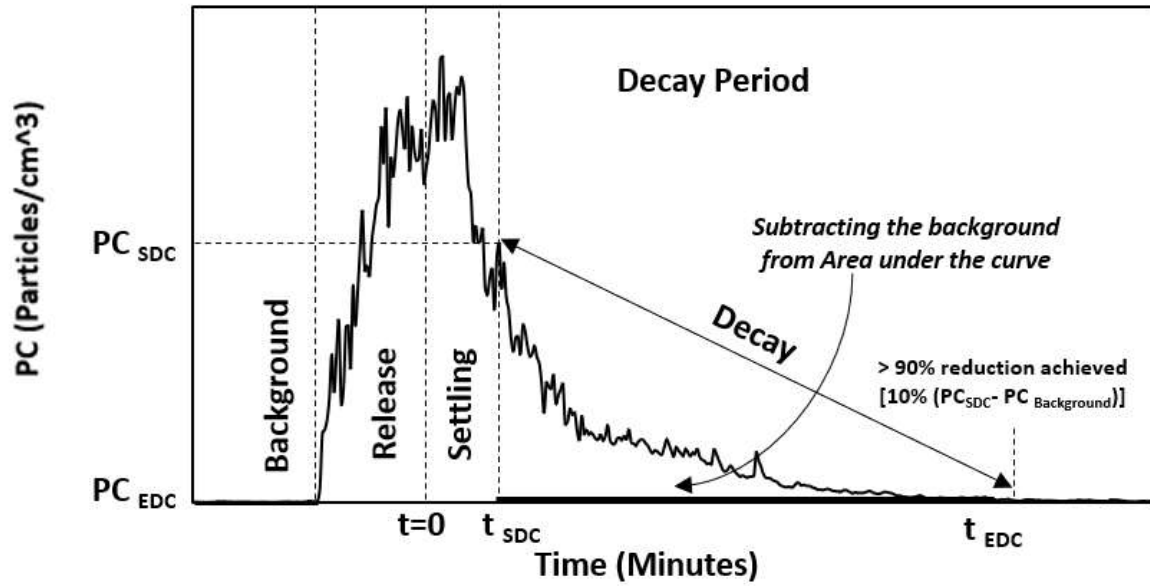


Figure C-2 Test periods for measured area under the curve.

C4 ANALYSIS OF DATA (Based on the Integral Method Described by Saman et al. [2025] and tail correction)

C4.1 The target volumetric airflow $V_{ECAi,target}$ shall be calculated using Equation C-1.

$$V_{ECAi,target} = (ECAi \times P_{Z,IRMM}) \quad (C-1)$$

where

$V_{ECAi,target}$ = target volumetric airflow, cfm (L/s)

$ECAi$ = equivalent clean airflow rate required per person in *IRMM* from Table 5-1, cfm per person (L/s/person)

$P_{Z,IRMM}$ = number of people in the space in *IRMM* as defined in Section 5.1

C4.2 The target air changes per hour (ACH_{target}) shall be calculated using Equation C-2 and the average time duration of the test after the release is stopped ($t_{test,90\%}$) using Equation C-3.

$$ACH_{target} = \left(\frac{60 \times V_{ECAi,target}}{V} \right) \quad (C-2)$$

$$t_{test,90\%} = \left(\frac{\ln 10}{ACH_{target}} \right) \times 60 \quad (C-3)$$

where

ACH_{target} = target air changes per hour, h^{-1}

$V_{ECAi,target}$ = global target volumetric airflow, cfm (L/s)

V = room (space) volume, ft^3 (m^3)

$t_{test,90\%}$ = time after release is stopped to achieve 90% reduction, minutes

C4.3 The background-corrected particle count $PC'_{ADn,E_n}(t)$ for all aerosol detectors AD_n ($n = 1 - 4+$) and size range E_n shall be calculated using Equation C-4.

$$PC'_{ADn,E_n}(t) = PC_{ADn,E_n}(t) - PC_{Background,E_n} \quad (C-4)$$

where

$$\begin{aligned} PC'_{AD_n, E_n}(t) &= \text{background-corrected particle count at time } t, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \\ PC_{AD_n, E_n}(t) &= \text{measured particle count at time } t, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \\ PC_{Background, E_n} &= \text{average background particle count for size range } E_n, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \\ AD_n &= \text{aerosol detector index, } n = 1, \dots, N \end{aligned}$$

C4.4 The measured areas under the curve for each aerosol detector, AD_n , and size range, E_n , over the decay period defined in Section C3 shall be calculated using Equation C-5.

$$AUC_{AD_n, E_n}^{meas} = \sum_{k=0}^{K-1} \frac{(t_{k+1} - t_k)}{2} [PC'_{AD_n, E_n}(t_{k+1}) + PC'_{AD_n, E_n}(t_k)] \quad (C-5)$$

where

$$\begin{aligned} AUC_{AD_n, E_n}^{meas} &= \text{measured area under the background-corrected decay curve for aerosol detector, } AD_n, \\ &\quad \text{and particle size range, } E_n, \text{ over the decay period} \\ k &= \text{discrete time-step index} \\ K &= \text{total number of time intervals spanning the decay period} \\ t_k &= \text{time corresponding to discrete measurement index} \\ t_{k+1} - t_k &= \text{duration of time interval between two successive measurements} \\ PC'_{AD_n, E_n}(t_k) &= \text{background-corrected particle counts at time, } t_k, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \end{aligned}$$

C4.5 The reduction ratio for each aerosol detector, AD_n , and particle size range, E_n , shall be calculated using Equation C-6.

$$R_{AD_n E_n} = \frac{PC'_{AD_n, E_n}(t_{EDC})}{PC'_{AD_n, E_n}(t_{SDC})} \quad (C-6)$$

where

$$\begin{aligned} R_{AD_n E_n} &= \text{reduction ratio for aerosol detector, } AD_n, \text{ and particle size range, } E_n; \text{ dimensionless} \\ &\quad \text{fraction representing the portion of background-corrected particle count remaining at} \\ &\quad \text{the end of the decay period relative to the start of the decay period.} \\ t_{EDC} &= \text{time at the end of the decay period, as defined in Section C3} \\ t_{SDC} &= \text{time at the end of the decay period, as defined in Section C3} \\ PC'_{AD_n, E_n}(t_{EDC}) &= \text{background-corrected particle counts at time } t_{EDC}, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \\ PC'_{AD_n, E_n}(t_{SDC}) &= \text{background-corrected particle counts at time } t_{SDC}, \text{ particles/in}^3 \text{ (particles/cm}^3\text{)} \end{aligned}$$

If $R_{AD_n E_n} \leq 0.10$, then the total areas under the curve for each aerosol detector, AD_n , and particle size range, E_n , over the decay period defined in Section C3 shall be calculated using Equation C-7.

$$AUC_{AD_n, E_n}^{tot} = AUC_{AD_n, E_n}^{meas} \quad (C-7)$$

where

$$\begin{aligned} AUC_{AD_n, E_n}^{tot} &= \text{total area under the background-corrected decay curve} \\ AUC_{AD_n, E_n}^{meas} &= \text{measured area under the background-corrected decay curve} \end{aligned}$$

If $R_{AD_n E_n} > 0.10$, then the monotonicity fraction F_{dec} and the global log-linearity coefficient R_{global}^2 for each aerosol detector, AD_n , and particle size range, E_n , over the decay period defined in Section C3 shall be calculated using Equations C-8 and C-9.

$$F_{dec} = \frac{1}{K} \sum_{k=0}^{K-1} I \left(PC'_{AD_n, E_n}(t_{k+1}) \leq PC'_{AD_n, E_n}(t_k) \right) \quad (C-8)$$

$$R_{global}^2 = \frac{1 - \sum_{k=0}^K (y_k - \hat{y}_k)^2}{\sum_{k=0}^K (y_k - \bar{y})^2} \quad (C-9)$$

where

F_{dec}	=	monotonicity fraction for the background-corrected decay for aerosol detector AD_n and particle size range, E_n ; dimensionless fraction of successive time intervals in the decay period for which the background-corrected particle count does not increase
K	=	number of time intervals in the decay period used to evaluate monotonicity; K equals the number of valid time points minus 1
k	=	discrete time-step index, $k = 0, 1, \dots, K - 1$
$PC'_{AD_n, E_n}(t_k)$	=	background-corrected particle count at time t_k for aerosol detector AD_n and particle size range, E_n , particles/in ³ (particles/cm ³)
R_{global}^2	=	coefficient of determination for the linear regression of y_k versus t_k over the full decay period (t_{SDC} , t_{EDC}); dimensionless measure of global log-linearity
y_k	=	natural logarithm of the background-corrected particle count at time t_k
$\hat{y}_k$	=	predicted value from the linear regression of y_k versus t_k
$\bar{y}$	=	mean of y_k over all data points used in the regression

If $F_{dec} \geq 0.95$ and $R_{global}^2 \geq 0.90$, the total area under the curve shall be calculated using Equation C-10.

$$AUC_{AD_n, E_n}^{tot} = \frac{AUC_{AD_n, E_n}^{meas}}{1 - R_{AD_n, E_n}} \quad (C-10)$$

where

AUC_{AD_n, E_n}^{tot}	=	total area under the background-corrected decay curve
AUC_{AD_n, E_n}^{meas}	=	measured area under the background-corrected decay curve
R_{AD_n, E_n}	=	reduction ratio defined by Equation C-6

If either $F_{dec} < 0.95$ or $R_{global}^2 < 0.90$, a continuous segment of at least five (5) consecutive data points from the final portion of the decay period for which $PC'_{AD_n, E_n}(t) > 0$ and the sequence exhibits a monotonic decrease shall be selected, and the following steps shall be performed:

- The decay constant using linear regression of the natural logarithm of the background-corrected particle count shall be calculated using Equation C-11.

$$\ln(PC'_{AD_n, E_n}(t)) = -k_{AD_n, E_n} t + b \quad (C-11)$$

where

$PC'_{AD_n, E_n}(t)$	=	background-corrected particle count at time t for aerosol detector AD_n and particle size range E_n , particles/in ³ (particles/cm ³)
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- k_{AD_n, E_n} = tail decay constant determined from linear regression of $\ln(PC'_{AD_n, E_n}(t))$ versus t over the selected tail segment, 1/time
- t = time during the decay period for the selected tail segment
- b = regression intercept from the linear regression of $\ln(PC'_{AD_n, E_n}(t))$ versus t , dimensionless

Verify that the coefficient of determination satisfies $R^2 \geq 0.85$.

- b. The tail area shall be calculated using Equation C-12.

$$AUC_{AD_n, E_n}^{tail} = \frac{PC'_{AD_n, E_n}(t_{EDC})}{k_{tail, AD_n, E_n}} \quad (C-12)$$

where

- AUC_{AD_n, E_n}^{tail} = estimated tail area under the background-corrected decay curve beyond t_{EDC}
- $PC'_{AD_n, E_n}(t_{EDC})$ = background-corrected particle count at the end of the decay period t_{EDC} , particles/in³ (particles/cm³)
- k_{tail, AD_n, E_n} = tail decay constant from Equation C-9

- c. The total area shall be calculated using Equation C-13.

$$AUC_{AD_n, E_n}^{tot} = AUC_{AD_n, E_n}^{meas} + AUC_{AD_n, E_n}^{tail} \quad (C-13)$$

where

- AUC_{AD_n, E_n}^{tot} = total area under the background-corrected decay curve (measured area plus tail correction)
- AUC_{AD_n, E_n}^{meas} = measured area under the background-corrected decay curve from t_{SDC} to t_{EDC} calculated using trapezoidal integration
- AUC_{AD_n, E_n}^{tail} = estimated area under the background-corrected decay curve beyond t_{EDC} calculated using Equation C-12

C4.6 The *equivalent clean airflow* for each aerosol detector, AD_n , and particle size range, E_n , shall be calculated using Equation C-14.

$$V_{ECA_i, AD_n, E_n} = \frac{V \times PC'_{AD_n, E_n}(t_{SDC})}{AUC_{AD_n, E_n}^{tot}} \quad (C-9)$$

where

- V_{ECA_i, AD_n, E_n} = *equivalent clean airflow* for each aerosol detector, AD_n , and particle size range, E_n , unit volume per unit time
- V = test volume, ft³ (m³)
- $PC'_{AD_n, E_n}(t_{SDC})$ = background-corrected particle count at the start of the decay period, particles/in³ (particles/cm³)
- AUC_{AD_n, E_n}^{tot} = total area under the background-corrected decay curve, including tail correction (if applied)

C4.7 The weighted average, $V_{ECA_i, AD_n, avg}$ averaged across each particle size range, E_1 , E_2 , and E_3 , and each aerosol detector using the weights W_{E1} , W_{E2} , and W_{E3} from Section 7.2.1.2 shall be calculated using Equation C-15.

Actual Weighted Average

$$V_{ECAi,ADn,avg} = V_{ECAi,ADn,E1} \times W_{E1} + V_{ECAi,ADn,E2} \times W_{E2} + V_{ECAi,ADn,E3} \times W_{E3} \quad (C-15)$$

where

$V_{ECAi,ADn,avg}$	=	volumetric airflow, aerosol detector n , averaged over all particle bins (E_1, E_2, E_3)
$V_{ECAi,ADn,E1}$	=	volumetric airflow, aerosol detector n , E_1
W_{E1}	=	particle size distribution weighting in the 0.3 to 1.0 micron range, [dimensionless], from Section 7.2.1.2
$V_{ECAi,ADn,E2}$	=	volumetric airflow, aerosol detector n , E_2
W_{E2}	=	particle size distribution weighting in the 1.0 to 3.0 micron range, [dimensionless], from Section 7.2.1.2
$V_{ECAi,ADn,E3}$	=	volumetric airflow, aerosol detector n , E_3
W_{E3}	=	particle size distribution weighting in the 3.0 to 10.0 micron range, [dimensionless], from Section 7.2.1.2

C4.8 The ensemble average, $V_{ECAi,avg}$, using the average of all the respective value of $V_{ECAi,ADn}$ calculated for the space in Section C4.5 shall be calculated using Equation C-16.

Ensemble Average

$$V_{ECAi,avg} = \frac{(V_{ECAi,AD1} + V_{ECAi,AD2} + V_{ECAi,AD3} + \dots)}{n} \quad (C-16)$$

where

$V_{ECAi,avg}$	=	ensemble average volumetric airflow
n	=	total number of aerosol detectors

C4.9 To determine the test outcome:

- Pass: The ensemble average $V_{ECAi,avg}$ shall be greater than or equal to the target $V_{ECAi,Target}$. If Normative Appendix C is used as an alternative method per Section 8.2.4.4, $V_{ECAi,existing} = V_{ECAi,avg}$, which shall be used to show compliance with Equation 6-1.
- Fail: The ensemble average $V_{ECAi,avg}$ is less than the target $V_{ECAi,target}$.

C5 REPORTING

The test report shall include the following:

- Test pass/fail outcome
- The ensemble average, $V_{ECAi,avg}$, and target global $V_{ECAi,target}$
- The weighted average ($V_{ECAi,ADn,avg}$) for each aerosol detector, highlighting the minimum
- The aerosol detector make, model, serial number, and date of last calibration
- Environmental conditions in the test area, including HVAC settings, air cleaners, position and status of all natural ventilation system (doors, windows, and other openings), temperature, humidity, supply and return vents. Interfering factors such as placement of the aerosol generator and detectors relative to neighboring vents shall be noted.
- Test area location and equipment placement
- Identification and status of operational devices:
 - All electrically powered devices that may contribute to particle decay during the test, including but not limited to fans, deodorizers, or other devices that emit additive or active substances into the air, whether operating in the room or air delivery system, shall be identified and their status clarified as either

- “contributing to decay” or “not”.
2. Devices identified as “contributing to decay” shall meet the safety requirements outlined in Normative Appendix A. This includes devices that may serve other functions but could impact air quality measurements.
 3. Any additional devices not identified as *air cleaning* devices shall also be noted in the report and certified as inactive or not contributing to decay to air quality during testing. A reference manual provided by the manufacturer explaining the function of the device shall be available upon request.
 4. A statement from the testing company verifying that no other unreported devices that may impact particle decay were operational during the test period shall be provided.

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INFORMATIVE APPENDIX D—RISK ASSESSMENT MODEL FOR DETERMINATION OF MINIMUM EQUIVALENT CLEAN AIRFLOW RATES

Minimum *equivalent clean airflow* rates per person (ECA_i) in Table 5-1 are intended to provide equivalent personal risk per hour so that all occupants of a space have the same infection risk over a given period regardless of space type. To do this we employ the widely-used model of infection risk originally proposed by Wells and Riley. The Wells-Riley model relates the probability of infection to the dose of infectious agent received using a Poisson distribution. To make a reasonable estimate with this model requires an understanding of the concentration of infectious pathogens an individual is exposed to as well as the infectious dose. A distribution of pathogen emission rate is calculated as a function of the number of infected people present, the viral load of their respiratory aerosols, their respiratory activity, and the probability that a single viable virion initiates an infection. The model accounts for the changes in viral load over time and differences in emission rate between people using laboratory-acquired quanta emission rates. A distribution (not a single value) is assumed for each model input. These distributions are sampled to create and simulate thousands of scenarios that are extreme, but still likely, using a statistical framework. The model output is a distribution of the ECA_i that is necessary to keep the probability of infection low in each scenario for a high percentage of the time.

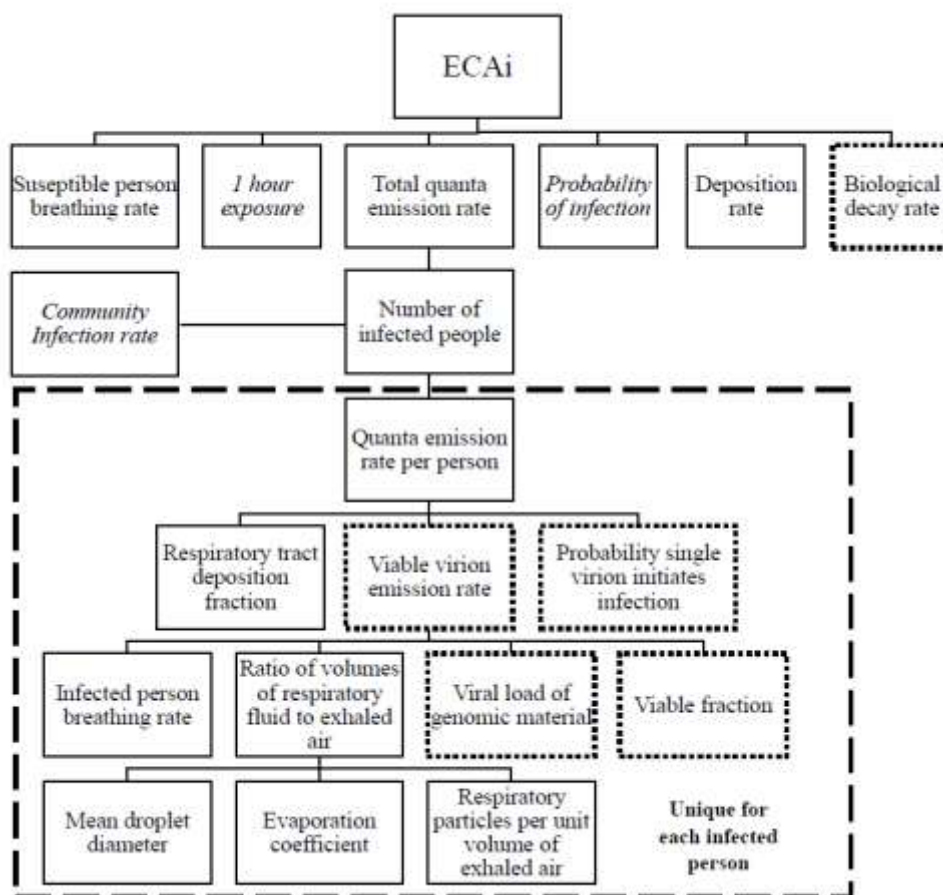


Figure D-1 Probabilistic model of infection ECA_i. Variables may vary as a function of metabolic and respiratory activity. Dashed box shows variables unique for each infected person. Dotted boxes show biological terms specific to SARS-CoV-2. Italic text shows deterministic inputs. All other boxes are probabilistic.

Figure D-1 shows the inputs and assumptions of the probabilistic model used to determine ECAi following Jones et al.¹² and Iddon et al.¹³. The quanta emission rate is unique for each infected person because of variation in key model inputs. These include breathing rate, viral shedding rate, mean respiratory droplet diameter, and aerosols per unit volume of exhaled air, for which values are sampled from distributions based on published data. When multiple infectors are present in a space, the total infectious quanta produced is the sum of their individual values. The number of infected people is generated according to a binomial distribution using the number of occupants and the community infection rate. This approach assumes one hour duration of exposure and accounts for deposition and biological decay.

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INFORMATIVE APPENDIX E—BUILDING READINESS PLAN TEMPLATE

E1 BUILDING READINESS PLAN AND ASSESSMENT WORKSHEETS

This standard requires the development of a *building readiness plan (BRP)* to document the sequences of operations, specifically the added engineering controls to the HVAC&R system to operate in *infection risk mitigation mode (IRMM)* in lieu of normal mode. This also indicates the evaluation of the engineering controls and the items chosen to achieve the *equivalent clean airflow* for infection control required.

Figure E-1 shows a sample table of contents for a *BRP*. Figure E-2 shows a sample building readiness assessment worksheet that can be used instead of a report. The worksheet can be downloaded from www.ashrae.org/241-2023.

Contents	
Introduction	3
HVAC Mitigation Strategies by Building	3
Building Description	4
Occupied Hours	4
Building Occupancy (Normal Mode and IRMM)	4
Outside Air	4
Filters	4
Air Cleaners—In HVAC	4
Air Cleaners—In Room	5
In-Room Fan Filter Units	5
Assessment and Planning	5
Non-HVAC Mitigation Strategies	5
Attachments	6
Attachment A—Owner’s HVAC IRMM Operations Guide	6
Attachment B—Critical Asset Inventory Management Plan	6
Attachment C—Testing Documentation	19

Figure E-1 Sample table of contents for a building readiness plan.

(Courtesy of Hanson Professional Services, Inc.)

Building Readiness Worksheet						Address	
Date						City, State	
This worksheet will help HVAC professionals to assess the ability of existing systems, particularly multiple-zone recirculating systems, to deliver the necessary <i>equivalent clean airflow for infection control</i> according to ASHRAE Standard 241-2023. It can also be used to document the Building Readiness Plan for a particular space or system. For more information on ASHRAE Standard 241, visit ashrae.org/241-2023							
Assessment Process Tasks						Referenced Section in 241-2023	
Step 1 - Gather Data						Section 8.2.3.1 and 8.2.3.2	
Obtain the following relevant documents (if available): record or as-built MEP drawings, Cx documents, BAS documentation, TAB reports							
Site observations must be performed, but can be done after Step 7 if there's sufficient documentation							
Step 2 - Inventory Occupied Spaces						Section 8.2.3.3 and Appendix B.1	
Determine space categorization related to Table 5-1 and ASHRAE 62.1 Table 6-1 and relevant occupancy details							
Step 3 - Inventory Equipment						Section 8.2.3.4	
Note the type and size of equipment serving each zone (e.g. VAV box or fan coil unit). Note the min and max airflow rates from the TAB report.							
Note the type and size of the central HVAC equipment serving the building (e.g. rooftop unit or AHU). Note the filter type that is installed, and outdoor airflow setpoints							

AHU Data		
AHU Designation	AHU-X	c- From drawings, BAS, or facility managers
AHU-X maximum supply airflow		c- This can come from TAB reports, design data, or BAS
AHU-X minimum supply airflow		c- This can come from TAB reports, design data, or BAS
AHU-X expected supply airflow		c- This airflow rate will be used to evaluate if additional Vecai is needed. The higher the airflow rate towards the maximum setpoint, the more conservative the results.
AHU-X filter MERV rating		c- This can be found from submittals, site observations, or design docs
AHU-X filter effectiveness		c- Table 7-3
AHU-X minimum OA airflow		c- This can come from TAB reports, design data, or BAS
AHU-X maximum OA airflow		c- This can come from TAB reports, design data, or BAS
AHU-X expected OA airflow		c- This airflow rate will be used to evaluate if additional Vecai is needed. c- The higher the airflow rate towards the minimum setpoint, the more conservative the results.

Zone Level Data									
Drawing Takeoffs or TAB Data						Veca			
Zone Designation	Occupancy Category (Table 5-1)	SF	People	SA CFM MAX	SA CFM MIN	Vacs	Vmv	ECAi per person	Vecai target

Figure E-2 Sample building readiness assessment worksheet.

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INFORMATIVE APPENDIX F—EQUIVALENT CLEAN AIRFLOW CALCULATOR

The Equivalent Clean Airflow Calculator can help determine the existing system's *equivalent clean airflow* for infection control as well as the modifications that achieve the target V_{ECAi} set by this standard.

The goal is to be able to evaluate new designs as well as existing building HVAC systems to help determine the *equivalent clean airflow* for infection control. The calculator can be downloaded from www.ashrae.org/241-2023.

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INFORMATIVE APPENDIX G—PRACTICAL GUIDANCE FOR EPIDEMIC OPERATION OF ENERGY RECOVERY VENTILATION SYSTEMS

ASHRAE Technical Committee (TC) 5.5, Air-to-Air Energy Recovery, along with ASHRAE’s Epidemic Task Force (ETF) Building Readiness Team, created *Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems* to evaluate energy recovery ventilators to determine if they should operate during the *IRMM* or what needs to be corrected to have them operate in *IRMM*. The guidance document can be downloaded from www.ashrae.org/241-2023.

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INFORMATIVE APPENDIX H—EXHAUST RE-ENTRAINMENT GUIDE

ASHRAE's Epidemic Task Force (ETF) Building Readiness Team created the *Exhaust Re-entrainment Guide* to evaluate potential for exhaust air re-entrainment into a facility's outdoor air. The guide can be downloaded from www.ashrae.org/241-2023.

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INFORMATIVE APPENDIX I—INFORMATIVE REFERENCES AND BIBLIOGRAPHY

I1 REFERENCES

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