STANDARD

ASHRAE Standard 241-2023

Control of Infectious Aerosols

Approved by the ASHRAE Standards Committee on June 24, 2023.

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Online Supporting Files: www.ashrae.org/241-2023

NOTE

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ASHRAE requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE.)

FOREWORD

Airborne transmission of communicable diseases occurs when a susceptible person inhales a sufficient number of active pathogens to cause an infection, i.e., an infectious dose. Engineering controls—dilution ventilation, filtration, and air disinfection—can reduce the concentration of active pathogens in the air, which tends to reduce risk of infection. Engineering controls are only one element of a well-designed risk management plan. They cannot eliminate risk and may not be as effective as other risk mitigation measures. However, inadequate control of indoor exposures has been demonstrated to contribute to elevated risk, so it is important to strike a balance between levels of control that create high risk and those that are beyond the point of diminishing returns.

Explicit requirements for airborne infection risk management have been absent for a century from indoor air quality (IAQ) standards with the exception of those written for health care facilities and laboratories. ASHRAE's predecessor society, the American Society of Heating and Ventilating Engineers (ASHVE), published ventilation recommendations in 1895 intended to reduce disease transmission, which were incorporated in a proposed 1914 model law and included in 22 U.S. state codes by 1922. In the 1930s, IAQ standards began adopting definitions of acceptable IAQ that focused on perceived air quality and control of typical chemical and particulate contaminants and that reset minimum ventilation rates to values generally much lower than the original ASHVE values. Since then, there has been growing awareness that indoor environments play a significant role in disease transmission. ASHRAE's early contributions on this topic include the 2009 "ASHRAE Position Document on Airborne Infectious Diseases," revised in 2022 as "ASHRAE Positions on Infectious Aerosols. Unfortunately, that awareness has not, until now, resulted in significant changes to standards and codes, despite concern that a large-scale, historical infectious event on the scale of the 1918 influenza pandemic was highly likely. Many smaller epidemics over the past several decades involving influenza and coronaviruses generated momentary concern and then faded from memory.

The COVID-19 pandemic caused enormous personal, societal, and economic damage, much of which resulted from the closure of public buildings due to widespread perception (supported by considerable evidence) that they were high-risk environments for infection transmission. This experience intensified discussion about the adequacy of existing IAQ standards, including code-basis standards such as ANSI/ASHRAE Standard 62.1, and added renewed urgency to calls for improved guidance. Recognizing that indoor environments were not well-prepared to mitigate the risk of COVID-19 transmission, ASHRAE formed its Epidemic Task Force (ETF) early in 2020. In a matter of months, the ETF produced a large body of guidance that has been well received and widely used. It addressed ventilation, filtration and air cleaning, air distribution, HVAC system operation, and commissioning for multiple building types, and presented a framework for planning effective upgrades. This guidance was not intended to set new enforceable minimum requirements, but it laid the groundwork for their development, which was envisioned as a logical next step.

The catalyst for the development of Standard 241 was discussion between ASHRAE and the White House COVID-19 Response Team about the need for new and better IAQ standards. ASHRAE was encouraged to take the lead in developing a new standard for control of airborne pathogens. On December 6, 2022, the ASHRAE Board of Directors authorized development of a standard with the goal of publishing in six months, and authorized the use of special procedures to make that possible. The project scope approved by the Board also stated the intention to "work to incorporate similar provisions into existing ASHRAE IAQ standards," specifically ANSI/ASHRAE Standards 62.1 and 62.2, perhaps as optional requirements. The Project Committee roster and the title, purpose, and scope of the standard were approved at the ASHRAE 2023 winter meeting, and the committee began its work in February. A draft was approved for advisory public review on May 11, 2023, that received over 1000 comments. The revised draft was approved for publication by the Project Committee on June 15, 2023, and the ASHRAE Standards Committee gave final approval on June 24, 2023. As was the case with the Epidemic Task Force, the work of SPC 241 was accomplished almost exclusively through frequent virtual meetings. The full Project Committee and Executive Committee held bi-weekly meetings, and the six working groups met no less than weekly throughout the development period. The two-day Executive Committee meeting on June 9–10, 2023, at ASHRAE headquarters to assemble the publication review draft was the sole in-person meeting during development of the standard.

The requirements of the standard apply to a wide range of building and space types. Key features include the following:

- *A requirement that systems comply with the requirements of the applicable ventilation and indoor air quality standards (e.g., ANSI/ASHRAE Standards 62.1 and 62.2 or ANSI/ASHE/ASHRAE Standard 170), including minimum ventilation rates. Standard 241 provides additional requirements for an infection risk management mode of operation (IRMM) that applies during periods when higher levels of infection risk mitigation are desired or are required by authorities based on public health data.*
- *Requirements for infection risk management given in terms of equivalent clean airflow rate in units of flow per occupant in a space (ECAi). The equivalent clean airflow requirement for a space or system can be met not only by outdoor air but also by filtered recirculated air and air disinfected by various other technologies. This allows flexibility for compliance using combinations of controls that optimize factors such as cost and energy use. ECAi requirements are based on extensive risk modeling, using inputs supported by peer-reviewed literature wherever possible. This analysis found flow rate per person to be the most useful and scalable way to represent requirements. To assist users in calculation of equivalent clean airflow, an updated version of the ETF equivalent outdoor air calculator spreadsheet is provided.*
- *Requirements for air distribution in mechanically ventilated, naturally ventilated, and mixed-mode buildings, and requirements for application of in-room air cleaners.*
- *Requirements for filtration and air cleaning that include laboratory testing requirements for performance and safety and calculation procedures for determining the contribution of filters and air cleaners to equivalent clean airflow requirements.*
- *Requirements for assessment, planning, and implementation of airborne infection risk reduction measures in existing buildings, documented in a building readiness plan that is modeled after the document of the same name developed by the ETF. These requirements address commissioning of installed systems to verify compliance.*
- *Requirements for operation and maintenance. Operational requirements also owe much to guidance developed by the ETF, while maintenance requirements are adapted from ANSI/ASHRAE Standard 62.1.*
- *Special requirements for residential and health care facilities which may house infected persons, including requirements for separation areas to be used by infected residents and additional ventilation when there are vulnerable occupants.*

Standard 241 is groundbreaking in a number of ways:

- *By creating a special operating mode for use when conditions warrant (IRMM), it introduces the concept of resilience into indoor air quality standards. A similar approach could be taken to developing requirements for systems to mitigate wildfire smoke.*
- *Expressing control requirements in terms of a quantity (ECAi) that integrates the impact of multiple controls. This concept could also be adapted and applied to other indoor air quality standards.*
- *The requirements for filter and air cleaner testing incorporated in this standard go well beyond what is found in current standards. They are a major step in the direction of creating uniform and effective technology-agnostic criteria for characterizing filter and air-cleaner performance and safety. Ultimately, this should enable more widespread and confident application of these technologies when method-of-test standards currently under development are published and available for reference.*

While the initial publication of Standard 241 provides a complete framework for planning, design, operation, and maintenance of systems that reduce risk of airborne infection transmission, there are ways in which it can be improved in the future with the benefit of needed research. Areas of need include the following:

- *A risk calculator implementing the methodology used to develop prescriptive equivalent clean airflow requirements that will support development of custom targets*
- *Refined air distribution guidance that accounts for contaminant removal effectiveness*
- *Guidance on use of computational fluid dynamics in complying with air distribution requirements*

The Project Committee will take up these and other issues in the next publication cycle.

The publication of Standard 241 is a notable achievement in terms of both its content and the speed with which it was produced. Both are due to the expertise of volunteers and staff, and their commitment to meet an ambitious schedule, along with the strong support of the ASHRAE Standards Committee and ASHRAE Board of Directors. It is their hope that the standard will be widely used to save many lives and help minimize the disruption to society of airborne diseases in the future.

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. May not substantially reduce transmission risk in all situations due to the diversity of infectious agents and personal susceptibility
c. 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

2.2 This standard does not determine the conditions under which *infection risk management mode* should be invoked.

2.3 No requirement in 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], or ANSI/ASHRAE/ASHE Standard 170 [3], 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 ordinary 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 nonengineering 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 the breathing zone, would have the same effect on infectious aerosol concentration as the sum of actual outdoor airflow, filtered airflow, and inactivation of infectious aerosols.

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.

long-range transmission: disease transmission that is due to aerosols emitted by an infector who is not in close proximity to (within approximately 3 ft [1 m] of) a susceptible occupant.

3.3 Abbreviations and Acronyms

ACCA	Air Conditioning Contractor of America Association, Inc.
ACH_T	target air changes per hour
AD	aerosol detector
AHAM	Association of Home Appliance Manufacturers
AHJ	*authority having jurisdiction*
AHU	air-handling unit
ASTM	ASTM International
BAS	building automation system
BRP	*building readiness plan*
CADR	clean air delivery rate
cfm	cubic feet per minute
CxP	commissioning provider

DCV	demand-controlled ventilation
ECAi	required *equivalent clean airflow* 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
HCHO	formaldehyde
HEPA	high-efficiency particulate air
IAQ	indoor air quality
IES	Illuminating Engineering Society
IRMM	*infection risk management mode*
ISO	International Organization for Standardization
L/s	liters per second
k_{nd}	infectious microorganism decay rate without *air cleaning* system operating
k_{td}	infectious microorganism decay rate with *air cleaning* system operating
L_{off}	first-order loss rate for the chemical that includes both air change and surface losses
m	meter(s)
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 breathing zone in *IRMM*
TAB	testing, adjusting, and balancing
UL	Underwriters Laboratory
UV	ultraviolet
V	test chamber volume
V_{ACS}	*air cleaning* system *equivalent clean airflow* rate
V_{ECAi}	minimum *equivalent clean airflow* rate required in the breathing zone to mitigate *long-range transmission* risk in *IRMM*
V_{MVS}	multizone *air cleaning* system *equivalent clean airflow* rate
V_{NV}	outdoor airflow rate from natural ventilation system
V_{OT}	the outdoor air intake flow rate, cfm (L/s)
V_{RC}	recirculated airflow rate cleaned by the *air cleaning* system
VSC	ventilation system controls
z_f	zone air fraction

4. COMPLIANCE

4.1 Prerequisites

4.1.1 The building 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 also approve the use of an equivalent standard as an alternative.

4.2 Requirements

4.2.1 All occupiable spaces, except as noted, shall comply with requirements of Sections 5 through 9.

4.2.2 All occupancies within the scope of ANSI/ASHRAE Standard 62.2 [2] shall also comply with Section 10.

4.2.3 The infectious aerosol removal efficiency (ε_{PR}) of mechanical fibrous filters shall be assigned a value of zero unless rated MERV-A 11 or higher when tested in accordance with ANSI/ASHRAE Standard 52.2 [5], Informative Appendix J. Any filter with an ePM2.5 50% rating from ISO Standard 16890-1 [6]

or certified by the manufacturer to be a high-efficiency particulate air (HEPA) filter is deemed to meet this requirement.

Exception to 4.2.3: Compliance prior to January 1, 2025, does not require use of ANSI/ASHRAE Standard 52.2, Informative Appendix J.

4.2.4 Previously installed *air cleaning* systems are required to comply with testing requirements of Section 7 and Normative Appendix A of this standard after January 1, 2025.

4.2.5 Application and installation of systems or equipment shall be carried out in accordance with the manufacturer's installation, operation, and maintenance instructions.

5. EQUIVALENT CLEAN AIRFLOW FOR INFECTION RISK MITIGATION

5.1 Minimum Equivalent Clean Airflow Rate

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

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

where

V_{ECAi} = minimum *equivalent clean airflow* rate required in the breathing zone to mitigate *long-range transmission* risk in *IRMM*, cfm (L/s)

ECA_i = *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 breathing zone in *IRMM*. $P_{Z,IRMM}$ shall default to the number of occupants used to calculate the ventilation rate per the applicable standard (see Section 4.1.1) or design occupancy or lower number of occupants during *IRMM* accepted by the owner.

5.1.2 Where the occupancy category for a proposed space or zone 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 the occupancy category for a proposed space or zone 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.

5.1.4 Breathing Zone in Dwelling Units. In a dwelling unit, the breathing zone consists of the habitable space as defined in ANSI/ASHRAE Standard 62.2 [2]. It is a region within the dwelling-unit habitable space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.

Informative Note: See Informative Appendix D, "Risk Assessment Model for Determination of Minimum Equivalent Clean Airflow Rates."

6. AIR DISTRIBUTION AND NATURAL VENTILATION

6.1 Clean Airflow Rate. The clean airflow rate to each zone, as shown in Figure 6-1, shall be greater than or equal to the minimum *equivalent clean airflow* required, as expressed by Equation 6-1.

$$\sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + V_{NV} \geq V_{ECAi} \quad (6\text{-}1)$$

where

z_f = the zone air fraction, calculated as the supply airflow rate to the zone divided by the total supply airflow rate to all zones

V_{OT} = the outdoor air intake flow rate, cfm (L/s)

V_{VMS} = multizone *air cleaning* system *equivalent clean airflow* rate, computed as a V_{ACS} from Section 7 for an *air cleaning* system whose output is shared amongst zones, cfm (L/s)

V_{ACS} = *air cleaning* system *equivalent clean airflow* rate, determined per Section 7 typically as a function of the recirculated airflow rate to be treated (V_{RC}), cfm (L/s)

V_{NV} = outdoor airflow rate from natural ventilation system, cfm (L/s)

V_{ECAi} = the minimum *equivalent clean airflow* rate required in the breathing zone, cfm (L/s)

6.2 Zone Air Distribution Category. Each ventilation zone shall be assigned a zone air distribution category as described in Table 6-1.

6.3 Natural Ventilation. Natural Ventilation systems shall be designed in accordance with the methods described in ANSI/ASHRAE Standard 62.1[1], ANSI/ASHRAE/ASHE Standard 170 [3], or an engineering analysis approved by the *AHJ*.

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

	ECAi	
Occupancy Category	**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

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

6.3.2 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

6.4 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 62.1 [1], ASHRAE/ANSI/ASHE Standard 170 [3], or an engineering analysis approved by the *AHJ*.

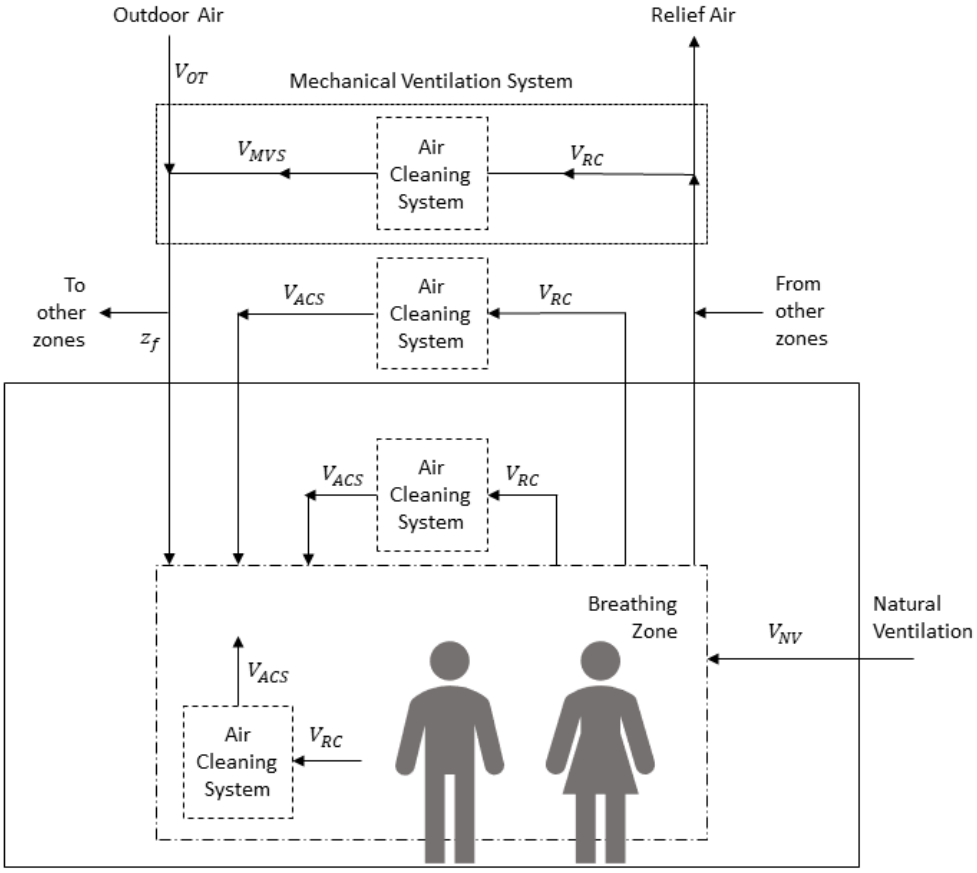

Figure 6-1 Sources of outdoor and clean air (for V_{RC}, see Section 7).

Table 6-1 Zone Clean Air Distribution Category

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

6.4.1 Zoned Mixed-Mode Ventilation. In zoned or spatial mixed-mode systems, where the ventilation mode varies among different zones of the space, satisfaction of Equation 6-1 shall be demonstrated for natural ventilation systems in natural ventilation zones and for mechanical ventilation systems in mechanical ventilation zones.

6.4.2 Changeover Mixed-Mode Ventilation. In changeover or temporal mixed-mode systems, where the ventilation mode for the whole space alternates according to space needs, satisfaction of Equation 6-1 shall be demonstrated individually for natural and mechanical ventilation systems.

6.4.3 Concurrent Mixed-Mode Ventilation. In concurrent mixed-mode systems, where both ventilation modes are used simultaneously, satisfaction of Equation 6-1 shall be demonstrated with combined effect of natural and mechanical ventilation systems.

Table 6-2 Air Cleaning System Categories

Location	Discharge Orientation			
	Horizontal (H) [d]	Up (U) [e]	Down (D) [f]	No Air Discharge (X)
Floor (F) [a]	FH	FU	FD	FX
Wall (W) [b]	WH	WU	WD	WX
Ceiling (C) [c]	CH	CU	CD	CX

a. Air inlet is at or below 6 ft (1.8 m) from the floor.
b. Air inlet is within 18 in. (0.5 m) of a wall.
c. Air inlet is above 6 ft (1.8) from the floor.
d. Air discharges within ±45 degrees of a plane parallel with the floor.
e. Air discharges within ±45 degrees of a plane perpendicular to the floor in an upward direction.
f. Air discharges within ±45 degrees of a plane perpendicular to the floor in a downward direction.

Table 6-3 Permitted In-Room Air Cleaning System by Air Distribution Category

Zone Air Distribution Category	Permitted Air Cleaning System Categories
Well-mixed	CD, CH, CU, CX, FD, FH, FU, FX, WD, WH, WU, WX
Natural	CH, CU, CX, FU, FX, WU, WX
Cross flow	CU, CX, FD, FH, FX, WH, WU, WD, WX
Downflow	CD, CX, WD, WX
Upflow	FU, FX, WU, WX

6.5 Air Cleaning Systems

6.5.1 *Air cleaning* systems shall not inhibit the development of the intended flow regime of the ventilation system as described in Section 6.5.1.1 and Section 6.5.1.2.

6.5.1.1 In-Room Air Cleaning System Categorization. In-room *air cleaning* systems shall be categorized in accordance with Table 6-2. All categories for which the system meets the requirement shall apply.

6.5.1.2 Permitted In-Room Air Cleaning System Applications. In-room *air cleaning* systems shall only be applied in accordance with Table 6-3.

7. AIR CLEANING

7.1 Testing Requirements. The effectiveness and safety of cleaning systems shall be determined by testing an *air cleaning* system or equivalent system in accordance with Section 7. A responsible party designated by the *authority having jurisdiction* (*AHJ*) shall certify air cleaner operational, performance, and safety equivalence. If acceptable to the *AHJ*, the responsible party may be the manufacturer of the *air cleaning* system.

The manufacturer shall review final test reports for accurate documentation of effectiveness and safety. The manufacturer shall certify that *air cleaning* systems are effective and safe for use under the requirements of ASHRAE Standard 241.

7.2 Calculated Effectiveness of Air Cleaning Systems

7.2.1 In-Duct Air Cleaning Systems that Clean Air in the Air-Handling Unit, Ductwork, or Plenum. Each *air cleaning* system located inside an air-handling unit (AHU), ductwork, or plenum that cleans air inside the AHU, ductwork, or plenum shall have an effectiveness reported as an infectious aerosol reduction efficiency (ε_{PR}). The ε_{PR} shall be determined by a single-pass test in accordance with Section 7 and Normative Appendix A. The *equivalent clean airflow* rate shall be calculated in accordance with Equation 7-1.

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

where

V_{ACS} = *air cleaning* system *equivalent clean airflow* rate due to the in-duct *air cleaning* system, cfm (L/s)

ε_{PR} = infectious aerosol reduction efficiency, determined in accordance with Section 7.3.1, Section 7.4.1.1, or Normative Appendix A, %

V_{RC} = recirculated airflow rate cleaned by the *air cleaning* system, cfm (L/s)

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

One System

$$\varepsilon_{PR} = \varepsilon_{PR,1} \tag{7-2a}$$

Two Systems

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

Three Systems

$$\varepsilon_{PR} = \left\{1 - \left[1 - \left(\frac{\varepsilon_{PR,1}}{100}\right)\right] \times \left[1 - \left(\frac{\varepsilon_{PR,2}}{100}\right)\right] \times \left[1 - \left(\frac{\varepsilon_{PR,3}}{100}\right)\right]\right\} \times 100 \tag{7-2c}$$

***N* Systems**

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

where $\varepsilon_{PR,j}$ is the infectious aerosol reduction efficiency of the j^{th} *air cleaning* system determined in accordance with Section 7 or Normative Appendix A.

7.2.2 In-Duct Air Cleaning Systems that Clean Air in the Occupied Zone. Each *air cleaning* system located inside an AHU, ductwork, or plenum that cleans air in the occupied zone and not inside the AHU, ductwork, or plenum shall have an effectiveness reported directly as an *equivalent clean airflow rate* (V_{ACS}, cfm [L/s]). The V_{ACS} shall be determined in accordance with Normative Appendix A.

Airflow conditions inside an AHU, ductwork, or plenum where the *air cleaning* system is installed shall be equivalent to airflow conditions in the ductwork for effectiveness testing. If no air is flowing through the AHU, ductwork, or plenum where the *air cleaning* system is installed, V_{ACS} shall be zero.

7.2.3 In-Room Air Cleaning Systems. Each *air cleaning* system located within a zone that cleans air within that zone shall have effectiveness reported directly as the *equivalent clean airflow* rate (V_{ACS}, cfm [L/s]) that shall be determined in accordance with Section 7 or Normative Appendix A.

7.3 Mechanical Fibrous Air Cleaning Systems. The effectiveness (delivered *equivalent clean airflow* rate) and safety of mechanical fibrous filters used inside HVAC systems, ductwork, or plenums, and in-room *air cleaning* systems that employ only mechanical fibrous filters to clean that air, shall be determined in accordance with Section 7.3.

7.3.1 Infectious Aerosol Removal Efficiency for Mechanical Fibrous Filters Installed In-Duct. The infectious aerosol removal efficiency (ε_{PR}) of mechanical fibrous filters installed within AHUs, ductwork, or plenums shall be determined in accordance with Equation 7-3 or Table 7-1.

$$\varepsilon_{PR} = W_{E1}\varepsilon_{E1} + W_{E2}\varepsilon_{E2} + W_{E3}\varepsilon_{E3} \tag{7-3}$$

where

ε_{PR} = infectious aerosol removal 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 $W_{E3} = 0.40$.

7.3.2 Equivalent Clean Airflow Rate for In-Room Air Cleaning Systems Using only Mechanical Fibrous Filters

7.3.2.1 Residential In-Room Air Cleaners Using Only Mechanical Fibrous Filters. Residential in-room air cleaners using only mechanical fibrous filters shall be tested using either ANSI/AHAM Standard

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

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

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

AC-1 [8] or ANSI/AHAM Standard AC-5 [9]. For air cleaners tested using ANSI/AHAM Standard AC-5, the reported m-CADR shall be the *equivalent clean airflow* rate (V_{ACS}). For air cleaners tested using AHAM Standard AC-1, the *equivalent clean airflow* rate shall be determined in accordance with Equation 7-4.

$$V_{ACS} = (W_s \times \text{CADR}_s) + (W_d \times \text{CADR}_d) + (W_p \times \text{CADR}_p) \quad (7\text{-}4)$$

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 $W_p = 0.40$. For residential in-room air cleaners tested using ANSI/AHAM Standard AC-1, the *equivalent clean airflow* rate (V_{ACS}) shall be zero where a clean air delivery rate for tobacco smoke is zero or not reported.

7.3.2.2 Commercial and Industrial In-Room Air Cleaners Using Only Mechanical Fibrous Filters. The *equivalent clean airflow* rate (V_{ACS}) of commercial and industrial in-room air cleaners using only mechanical fibrous filters shall be determined in accordance with Normative Appendix A using a custom test method similar to that described in ANSI/AHAM AC-1[8] adapted with the chamber size criterion outlined in Section A1.2.2.

7.3.3 Safety Requirements for Air Cleaning Systems Using Only Mechanical Fibrous Filters

7.3.3.1 Mechanical Fibrous Filters Installed In-Duct. There are no additional safety testing requirements for mechanical fibrous filters used inside HVAC systems, ductwork, or plenums.

7.3.3.2 In-Room Air Cleaning Systems Using Only Mechanical Fibrous Filters. In-room *air cleaning* systems that use only fibrous filters to clean the air are exempt from all safety testing requirements in Normative Appendix A except the noise testing requirement in Normative Appendix A, Section A1.4.1.3.

7.4 Air Cleaning Systems that Inactivate Infectious Aerosols. The effectiveness and safety of air cleaners with technologies that inactivate infectious aerosols shall be determined in accordance with Section 7.4. This applies to all *air cleaning* technologies that provide microorganism inactivation or enhanced removal from the airstream, acting alone or in combination with mechanical fibrous filters, including ultraviolet, electrostatic, photocatalytic, and ionizing *air cleaning* systems.

7.4.1 In-Duct Air Cleaning Systems. Effectiveness and safety of air cleaners installed inside HVAC systems, ductwork, or plenums that have an infectious aerosol reduction mechanism other than or in addition to mechanical fibrous filters shall be determined in accordance with Section 7.4.1.1 or Section 7.4.1.2.

7.4.1.1 In-Duct Ultraviolet Germicidal Irradiation. The infectious aerosol reduction efficiency of ultraviolet lights for use in AHUs and air ducts shall be determined in accordance with ANSI/ASHRAE

Standard 185.1 [10] methodology with MS2 as the challenge organism. The safety of in-duct ultraviolet germicidal irradiation shall be determined in accordance with the safety requirements of Normative Appendix A.

7.4.1.2 Other In-Duct Air Cleaning Systems. The effectiveness and safety of all other in-duct air cleaners that treat the air shall be determined in accordance with Normative Appendix A.

7.4.2 In-Room Air Cleaning Systems. Effectiveness and safety of in-room air cleaners that have an infectious aerosol reduction mechanism other than, or in addition to, mechanical fibrous filters shall be determined in accordance with Section 7.4.2.1 or Section 7.4.2.2.

7.4.2.1 Upper-Room Ultraviolet Germicidal Irradiation. For the purposes of this standard, the effectiveness and safety of upper-room germicidal irradiation systems shall be determined in accordance with Normative Appendix A.

7.4.2.1.1 Upper-room ultraviolet germicidal irradiation systems shall be installed and operated in accordance with ANSI/IES RP-44-21 [11].

7.4.2.2 Other In-Room Air Cleaning Systems. The effectiveness and safety of all other in-room air cleaners that treat the air shall be determined in accordance with Normative Appendix A.

8. ASSESSMENT, PLANNING, AND IMPLEMENTATION

Requirements of this section do not apply to occupancies covered by ANSI/ASHRAE Standard 62.2 [2] except as specified in Section 10.

8.1 Building Readiness Plan (BRP). The *BRP* shall be created after the assessment, planning, and implementation phases to describe the engineering and nonengineering 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.

a. 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, 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 zone-level ventilation matrix that specifies the V_{ECAi} target for each risk mitigation mode. 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.
b. The nonengineering controls section shall include any requirements for allowed changes in building occupancy levels ($P_{z,IRMM}$), personal protection equipment use, social distancing, and cleaning. The *BRP* shall include any testing or safety documents required by this standard.

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:

a. Buildings or systems are altered
b. Changes are made to building use or space occupancy category
c. A significant change in occupancy density occurs
d. 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 system (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. Walk the facility and determine what HVAC systems are installed, and 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 62.1 [1], Table 6-1
b. A dwelling unit
c. For health care, the appropriate function of space from ANSI/ASHRAE/ASHE Standard 170 [3] Table 7-1 (inpatient), Table 8-1 (specialized outpatient), Table 8-2 (general outpatient), and Table 9-1 (support spaces)

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

8.2.3.5 Multifamily Residential Buildings, Including Dorms and Hotels. In multiunit 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 10.2.2.

In hotels, dormitories, and other public residential buildings, dwelling-to-dwelling transfer air shall be assessed in accordance with Section 10.2.2.

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.

8.2.3.6 Potential Separation Areas. Potential separation spaces shall be evaluated as follows:

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

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. Outdoor, supply and return airflow quantities 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 111 [12] or equivalent as allowed by the *AHJ* to determine supply, return, and outdoor airflow
d. A tracer gas dilution evaluation in accordance with ASTM E741 [13] to determine outdoor airflow

8.2.3.9 Minimum Outdoor Airflow Requirements. The minimum outdoor airflow required 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 (VSC). 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 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. See Section 7 for information on how to review, analyze, and document the V_{ECAi} provided by each of the *air cleaning* systems.

8.2.3.17 Controlling Sensors. The controlling sensors on air delivery systems that will be adjusted to achieve target V_{ECAi} 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 operations for HVAC systems that could be affected by additional engineering controls.

8.2.3.19 Existing Engineering Controls. If any additional 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_{ECAi}. The need for additional engineering controls to meet the $V_{ECAi,target}$ 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 to the existing system are required.

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. Controls 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. Determine the required $V_{ECAi,target}$, where $V_{ECAi,target}$ is equal to V_{ECAi} as determined by Equation 5-1 using the $P_{z,IRMM}$ accepted by the owner. Determine the current system $V_{ECAi,existing}$ that is the combination of the following:

a. Outdoor air quantity introduced to the building as identified in the assessment phase
b. Recirculation air that is subjected to existing, functioning air cleaners and calculated based on the assessment phase

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

$$V_{ECAi,target} - V_{ECAi,existing} = V_{ECAi,differential} \quad (8\text{-}1)$$

where $V_{ECAi,existing}$ is determined by Equation 8-2 for the system as found.

$$V_{ECAi,\,existing} = \sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + \sum V_{NV} \quad (8\text{-}2)$$

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

If $V_{ECAi,differential}$ 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_{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 as described in Normative Appendix C. If the Normative Appendix C approach is used, it shall include testing of at least 10% of all occupied space types, with a minimum of two randomly selected locations of duplicate space types.

8.2.4.4 Select Engineering Controls. Potential options to add $V_{ECAi,modifications}$ shall be determined based on

a. Physical constraints
b. Predicted V_{ECAi} (See Informative Appendix F, "Equivalent Clean Airflow Calculator.")

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

a. If demand-control ventilation (DCV) is deactivated in *IRMM*, the design or measured outdoor air shall be used to calculate $V_{ECAi,delivered}$.
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 $V_{ECAi,delivered}$.
c. If the fan speed is set to constant during *IRMM*, then the measured or resulting airflows shall be used to calculate $V_{ECAi,delivered}$.
d. If the fan speed is allowed to modulate, then the minimum airflow set point shall be used to calculate $V_{ECAi,delivered}$.

8.2.4.6 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 occupied space with $V_{ECAi,target}$.

8.2.4.7 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 ASHRAE Standard 230 [14] in addition to the following:

a. Test all modes of operation.
   1. Normal mode: occupied and unoccupied
   2. *IRMM*: occupied and unoccupied
b. Test all adjustments to outdoor air control and delivery.
c. 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.

d. Confirm air cleaner efficiency per Section 7 and Normative Appendix A.
e. 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_{ECAi} 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_{ECAi} 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 Section 11.1.4.1 of ANSI/ASHRAE/IES Standard 90.1 [15], 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 202 [16], Section 6, the OPR shall include potential engineering and nonengineering 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 $V_{ECAi,target}$.

8.3.6 Equipment Checklists. The CxP shall include on the equipment checklist information about the control devices and equipment required to achieve the $V_{ECAi,target}$.

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. If the Normative Appendix C approach is used, it shall include testing of at least 10% of all occupied space types, with a minimum of two randomly selected locations of duplicate space types.

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 1.4 [17] for additional information required 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

Requirements of this section do not apply to occupancies covered by ANSI/ASHRAE Standard 62.2 [2] except as specified in Section 10.

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 operator and building owner, *AHJ*, or public health official shall determine which mode of operation shall be used for the facility. 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 62.1 [1], Section 6.2.6.1.4. Ventilation that is switched to an occupied standby mode zone 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 when the space is occupied.
d. Demand-control ventilation (DCV) shall operate as noted in the *BRP*.
e. In multiunit residential buildings, including dormitories and hotels, ventilation and exhaust system that serve multiple dwelling units shall operate continuously at design settings, without setback.

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 nonengineering controls must be implemented to achieve the revised $V_{ECAi,target}$.

9.1.7 Operation at Varying Fan Speeds. Systems with variable speed fan control shall have it confirmed that their fan speed control aligns with the *BRP* and resulting V_{ECAi} delivered.

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 space aligns with the zone air distribution category, and with the *BRP* as noted, per Table 6-1. If any form of variable-air-volume or demand-controlled ventilation system is used for energy conservation, it shall not compromise pressure balancing and control.

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 occupants shall have signage indicating

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 *air cleaning* 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 and those used for demand-controlled ventilation, including CO_2 sensors, and handheld CO_2 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 i5n ASHRAE Standard 41.2 [19] or ASHRAE Standard 111 [12].	Every 2 years
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, ±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 111 [12] 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 3 years

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 180 [18] 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.

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

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

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 62.1 [1], 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 Control Systems. Remote or off-site access to building control systems, if present, shall be tested for successful control on a quarterly basis.

9.2.2.3.1 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 0415 [21], Section 3.)

10. DWELLING UNITS—ADDITIONAL REQUIREMENTS

10.1 General Requirements

10.1.1 All toilets shall be provided with lids.

10.1.2 All plumbing traps shall be filled with water.

10.1.3 Building Readiness Plan (BRP). A *BRP* shall be created after the assessment, planning and implementation phases to describe the engineering and nonengineering controls that the dwelling unit and its systems will use to achieve its current target *equivalent clean airflow* for infection control (V_{ECAi}) during *IRMM*. Section 8.2.4.3 shall be used to determine if additional engineering controls are required. The *BRP* shall be either a standalone document or a section of an existing operations and maintenance plan.

10.2 Existing Buildings—Single Family and Multifamily Dwellings

10.2.1 Forced-air HVAC systems serving more than one dwelling unit shall be blocked off from any dwelling unit occupied by either an infected or at-risk resident. Portable HVAC and air filtration/*air cleaning* units shall be provided in blocked off spaces.

10.2.2 All joints, seams, penetrations, openings between door assemblies and their respective jambs and framing, and other sources of air leakage through wall and ceiling assemblies shall be caulked, gasketed, weather stripped, wrapped, or otherwise sealed to limit air movement. Doors between the garage and the dwelling units shall be gasketed or made substantially airtight with weather stripping. Any common-corridor ventilation system shall be operated to maintain a positive pressure in the corridor relative to each dwelling unit.

10.3 Separation Area for Infected Occupants. When a household member is known to be infected, a separate fully enclosed space shall be used as a separation area. For the separation area, *equivalent clean airflow* supply shall meet or exceed required V_{ECAi} per Equation 5-1 using the health care patient room occupancy category listed in Table 5-1.

10.4 Dwelling Units with Vulnerable Occupants. Dwelling unit *equivalent clean airflow* supply shall meet or exceed required V_{ECAi} per Equation 5-1 using the health care patient room occupancy category listed in Table 5-1.

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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. TESTING PROCEDURE

Where testing of the effectiveness or safety elements of *air cleaning* systems falls within the scope of a national consensus standard approved by the *AHJ,* these elements of the systems shall be tested in accordance with the applicable standard per the requirements of Section 7.

The consensus standards that shall be used for determining effectiveness are as follows:

a. ANSI/ASHRAE Standard 52.2 [5] (both the regular filter test and the bioaerosol test for non-UV-only devices specified in Appendix L). (***Informative Note:*** After January 1, 2025, MERV-A ratings using Appendix J shall be required.)
b. ISO 16890-1 [6]
c. ANSI/AHAM AC-1 [8]
d. ANSI/AHAM AC-5 [9]
e. ANSI/ASHRAE 185.1 [10]

The consensus standards that shall be used for determining safety are as follows:

a. UL 2998 [22]
b. ASTM D8407 [23]
c. ISO 14644 [24]

Where the effectiveness and/or safety performance of an *air cleaning* system is not covered by any of the above consensus standards, custom tests shall be performed by a third-party, independent laboratory in accordance with the conditions in Normative Appendix A.

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 in the test environment shall be equivalent and correspond to the intended application setting.

A1.2 General Testing Requirements. Performance tests of *air cleaning* systems, whether mounted inside an air-handling unit (AHU) ductwork or plenum or placed in the occupied zone, shall be performed in accordance with Section A1.2.

A1.2.1 Testing Laboratory. Testing shall be performed by a third-party independent laboratory. The *air cleaning* system manufacturer, or any entity owned by the system manufacturer, shall not perform the test. All testing laboratories shall comply with the requirements of ISO/IEC 17025 [25] or equivalent.

A1.2.2 Test Chamber Requirements. The test chamber shall comply with the following:

a. Volume shall be at least 800 ft^3 (22.7 m^3). For *air cleaning* systems with an operational volume greater than 800 ft^3 (22.7 m^3), the ratio of the test chamber volume to the *air cleaning* system *equivalent clean airflow* rate shall be greater than 1.7 for I-P units (ft^3/cfm) or 0.101 for SI units (m^3/[L/s]).
b. Surfaces shall be smooth, nonporous, produce minimal emissions, and react minimally with the *air cleaning* system.
c. Surfaces shall be electrically grounded.
d. Shall have fans to provide sufficient mixing, as defined in ASTM Standard D6670 [26], Section 8.4, or equivalent.
e. Shall be sufficiently airtight during testing (leakage of less than 0.05 ach).
f. Shall be capable of flushing or treating air between tests.
g. Shall maintain temperature throughout the duration of testing at 73°F ± 5° F (23°C ± 3°C).
h. Shall maintain relative humidity throughout the duration of testing at 50% ±10%.
i. Air-handling systems associated with chamber ventilation shall be powered off during testing to minimize recirculation, unless testing with a side duct is necessary under Section A1.2.3.2, in which case air-handling systems intended to clean the air before or after tests shall be powered off during the testing.

A1.2.3 Test Duct Requirements

A1.2.3.1 For in-duct *air cleaning* systems that clean air in the AHU, ductwork, or plenum, that can be tested for a single-pass infectious aerosol removal efficiency, the test duct shall be as described in ANSI/ASHRAE Standard 52.2 [5] ANSI/ASHRAE Standard 185.1 [10], or per the system manufacturer's published specifications.

A1.2.3.2 For in-duct *air cleaning* systems that clean air in the occupied zone, the test duct shall be a recirculating duct connected to or within the test chamber described in Section A1.2.2. 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.

A1.2.4 Air Cleaner Equipment Installation. *Air cleaning* system equipment shall be installed in the test chamber or test duct following the manufacturer's published specifications and in a manner that minimizes impacts on other testing procedures. The third-party independent test laboratory shall certify that the installation meets these conditions or describe any potential impacts in the testing report.

A1.2.5 Quality Assurance and 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 cleaned and sterilized between tests as necessary to eliminate cross-contamination between tests.
c. The test equipment shall be placed within the chamber prior to testing.
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 (microbiological or chemical analyte) shall be collected prior to each test.
f. A minimum of three replicates for each test condition (*air cleaning* system OFF and *air cleaning* system ON) shall be performed, for a minimum of six total tests per *air cleaning* system. Effectiveness shall be calculated using an average of these replicates.

A1.2.6 General Reporting Requirements. The third-party 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 and the names of the operators
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. A quantification of uncertainty, based on replicate testing and methods detection limits

A1.2.7 Testing Certification Requirements. The independent, third-party laboratory shall prepare, review, and approve the test report.

A1.3 Effectiveness Testing Requirements. Effectiveness testing for all *air cleaning* systems covered by a consensus standard listed in Section A1 shall be performed following the methodology of that standard with the challenge microorganism specified in Section A1.3.2. The effectiveness testing for any *air cleaning* system not covered by a consensus standard listed in Section A1 shall conform to the following additional requirements.

A1.3.1 Biosafety Requirements. All bioaerosol testing and microbial procedures shall be conducted in accordance with the current version of the CDC/NIH *Biosafety in Microbiological and Biomedical Laboratories* [27].

A1.3.2 Test Microorganism and Microbiological Procedures. All effectiveness testing utilizing microorganisms shall be performed with the nonenveloped bacteriophage MS2 (host *Escherichia coli*). The test microorganism shall be aerosolized by nebulizing a microbial suspension to produce discrete particles. Bioaerosol

samples 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 using impingers, impactors, or other acceptable sampling methods as determined by the third-party testing laboratory. The test microorganism samples shall be collected, handled, and analyzed in the same manner for all test iterations. Each collected sample shall be plated in triplicate.

Informative Note: Bacteriophage MS2 (host *Escherichia coli*) is chosen because of its established properties as a relatively safe and conservative infectious pathogen viral surrogate, as this standard is forward-looking and not specific to a currently known pathogen. Air cleaner manufacturers are encouraged to test with specific infectious pathogens and their appropriate surrogates to determine more specific performance claims against known infectious pathogens that are outside the scope of this standard.

A1.3.3 Effectiveness Calculations. The effectiveness calculations shall

a. Account for background reduction of the test microorganism
b. Compare averages of the replicates with the *air cleaning* system OFF to the averages of the replicates with the *air cleaning* system ON
c. For microorganism recoveries lower than the limit of detection, use the value of the limit of detection for effectiveness calculations

A1.3.3.1 Effectiveness of In-Room Air Cleaning Systems. The effectiveness of an *air cleaning* system operating within a room shall be reported as an *equivalent clean airflow* delivery rate, determined using the procedure presented in Stephens et al. [28] and following Equation A-1:

$$V_{ACS} - V(k_{td} - k_{nd}) \quad \text{(A-1)}$$

where

V_{ACS} = *air cleaning* system *equivalent clean airflow* rate, cfm (L/s)
V = test chamber volume, ft^3 (L)
k_{td} = infectious microorganism decay rate with *air cleaning* system operating, $minute^{-1}$ (s^{-1})
k_{nd} = infectious microorganism decay rate without *air cleaning* system operating, $minute^{-1}$ (s^{-1})

A1.3.3.2 Effectiveness of In-Duct Air Cleaning Systems. The effectiveness of an *air cleaning* system located in an AHU, ductwork, or plenum shall be determined in accordance with

a. Single-pass tests, such as those described in ANSI/ASHRAE Standard 52.2 [5], ANSI/ASHRAE Standard 185.1 [10], or equivalent, and reported as an infectious aerosol reduction efficiency (ε_{PR}). This shall apply to in-duct *air cleaning* systems that clean the air in the AHU, ductwork, or plenum.
b. Tests meeting the conditions in Normative Appendix A with test air recirculating through a side duct or a duct within the test chamber, and with effectiveness reported as an *equivalent clean airflow* delivery rate using Equation A-1. This shall apply to in-duct *air cleaning* systems that clean the air in an occupied zone.

A1.3.3.3 Effectiveness Testing Reporting Requirements. In addition to the general reporting requirements, the third-party independent testing laboratory shall include the following information in the test report:

a. A description of the aerosolization equipment, procedures (including the composition of the microbial suspension), 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, as specified per the requirements stated in Normative Appendix A relevant to the *air cleaning* system deployment (in-room or in-duct)

A1.4 Safety Testing Requirements. *Air cleaning* systems shall be tested for safety under the requirements of Section A1.4.

A1.4.1 Required Tests. *Air cleaning* systems shall be tested for the following.

A1.4.1.1 Chemical Analytes Released by Air Cleaning Systems or Resulting from Chemical Reactions in the Air. Air cleaners shall be tested for analytes according to Table A-1. An *air cleaning* system exceeding the target for any single analyte in Table A-1 shall be noted in the test report, and the *air cleaning* system shall not be used under the provisions of ASHRAE Standard 241.

All *air cleaning* systems shall be tested in-chamber as described in Section A1.2.2. for ozone, formaldehyde, and airborne particulates. Testing for formaldehyde and particulates can be determined concurrently or independently. Formaldehyde testing shall be conducted in the presence of a single-pulse injection

of limonene resulting in approximately 25 μg/m^3 (4.5 ppb$_v$) initial gas concentration in the chamber. The experiment shall last at least four hours to allow reactive chemistry to occur. Loss rates for the air cleaner OFF shall be determined according to the procedure described in Stephens et. al [28], or equivalent. The average emission rate for formaldehyde over the test period shall be determined using Equation A-2:

$$E = V\left(L_{off}C_{t=\Delta t} + \frac{C_{t=\Delta t} - C_{t=0}}{\Delta t}\right) \quad \text{(A-2)}$$

where

E = emission rate, μg/h

V = volume of the chamber, m^3

L_{off} = first order loss rate for the chemical that includes both air change and surface losses (see Stephens et. al)

$C_{t=\Delta t}$ = concentration at the end of the test period, μg/m^3

$C_{t=0}$ = concentration at the beginning of the test, μg/m^3

Δt = total length of test in h; minimum = 4

Exception to A1.4.1.1: *Air cleaning* systems are not required to be tested for the analytes in Table A-1 if they do not

1. Add an active agent to react either on surfaces or in the gas phase or
2. Add energy capable of changing the charge on molecules or changing the composition of the air, on its own or with the aid of a catalyst.

This determination shall be made by the third-party, independent testing laboratory based on *air cleaning* process information provided by the *air cleaning* system manufacturer. Written justification for any exclusions from analyte testing according to Table A-1 shall be included in the test report.

A1.4.1.2 Noise. *Air cleaning* systems that include a fan, blower, or other means to generate air movement shall be tested for sound power level.

An average A-weighted sound power pressure level (unit: dB re 20 μPa) shall be determined at a distance of 3.3 ft (1.0 m) from the *air cleaning* system per ANSI/AHAM AC-2 [29] or equivalent method. The measured sound power pressure level shall be included in the safety test report.

Informative Note: Information on acceptable noise levels in occupied building spaces can be found in the 2019 *ASHRAE Handbook—HVAC Applications* [11], Chapter 49, "Noise and Vibration Control."

A1.4.1.3 Ultraviolet Radiation. In-room *air cleaning* systems that generate electromagnetic radiation with a wavelength between 100 and 400 nm shall not exceed the threshold limit values (TLVs) in the *2022 Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)* [30] for the wavelength(s) emitted by the system. The ultraviolet TLVs shall not be exceeded in the space served by the system at a height of 5 ft 11 in (1.8 m) or below. Conformance with the TLV shall be confirmed by measurements as described in ANSI/IES RP-27.1.22 [20], ANSI/IES RP-44-21 [11], or equivalent.

A1.4.1.4 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.

A1.4.2 Safety Testing Reporting Requirements. In addition to the general reporting requirements, the third-party, 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. Description of the test method and monitoring equipment (including limits of detection) used for formaldehyde
c. Description of monitoring equipment used for measurements of particulate matter
d. The amount of limonene introduced into the chamber during each test and the tests conducted with limonene present
e. A matched set of concentration data for duplicate testing with the *air cleaning* system off and the *air cleaning* system on
f. Clear indication whether a tested *air cleaning* system exceeded targets outlined in Table A-1 during testing

A1.4.3 Manufacturer's Certification. The manufacturer shall review the safety test report and certify that the product is safe to the best of their knowledge and belief.

Table A-1 Required Analytes for Safety Testing

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

(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 planned to be allowed during *IRMM*
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, 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—for example, a health care 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 62.1 [1], Section 6.2.
b. Indoor Air Quality Procedure (performance). Determine outdoor air and *air cleaning* systems compliance per ANSI/ASHRAE Standard 62.1 [1], Section 6.3.
c. Natural ventilation in nonresidential spaces shall use ANSI/ASHRAE Standard 62.1 [1], 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 62.2 [2], Section 4 or Normative Appendix A, to determine the required ventilation rates.
e. Health care spaces shall use ANSI/ASHRAE/ASHE Standard 170 [3], 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 180 [18]. 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. CO_2

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 effectiveness [31].

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 Owners Project Requirements (OPR). The OPR shall include

a. V_{ECAi} 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

a. 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.)
b. A complete sequence of operation and control diagrams for system operation in *IRMM*
c. A table of the normal mode and *IRMM* objectives to summarize the engineering controls applied to this facility
d. 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 (ECAi) OF A SINGLE OCCUPIED SPACE BY MEANS OF TRACER AEROSOL DECAY

This appendix presents an in-place method [32] 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 UVC. The technique is based on measurement of the decay rate of tracer particles. [33–39] ECAi metrics are calculated according to the decay rate of the tracer particles [34] during their removal from the space and compared to the target 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 of 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 52.2 [5].
b. **Aerosol detector (AD).** Instrument that measures tracer aerosol concentrations. Aerosol detectors shall have demonstrated accuracy within ±10% of the reading of an ISO qualified reference aerosol detector [36]. Other aerosol detectors (e.g., instantaneous biological analyzer and collectors (IBACs), for fluorescent-tagged polystyrene beads; qPCR; and DNA sequencers, for DNA-tagged particles) shall have demonstrated accuracy, calibrated to within ±10% of a standard reference.
c. **Tracer particles.** Particles 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 [32,35,37,38,40]; DNA-tagged particles [34,41,39]; fluorescent-tagged polystyrene latex beads [39]; smoke/other particulate-based tracers [31]. 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. All equipment shall be calibrated within one year and in accordance with manufacturer's specifications.
b. Select the test space(s). In rooms larger than 900 ft^2 (83 m^2), multiple test areas shall be used to cover the space.
c. 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.
d. Movement in the test area shall be restricted for the duration of the test.
e. There shall be no other aerosol generating sources, natural or mechanical, active in the test space(s).
f. Measure and record the volume of the space.
g. 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 15×15 ft [4.5×4.5 m], the quadrants can be smaller.) The aerosol generator and aerosol detectors shall be placed at the same height within the breathing zone 3 to 72 in. (1.2 cm to 1.8 m) from 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.
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. (***Informative Note:*** Depending on the aerosol detector and tracer particle used, high flow rates may necessitate greater than three times the background particle count [31,32,34].) The time at which the generator is turned off is $t = 0$ minutes.
c. **Settling period.** The six-minute period beginning when the aerosol generator is turned off.

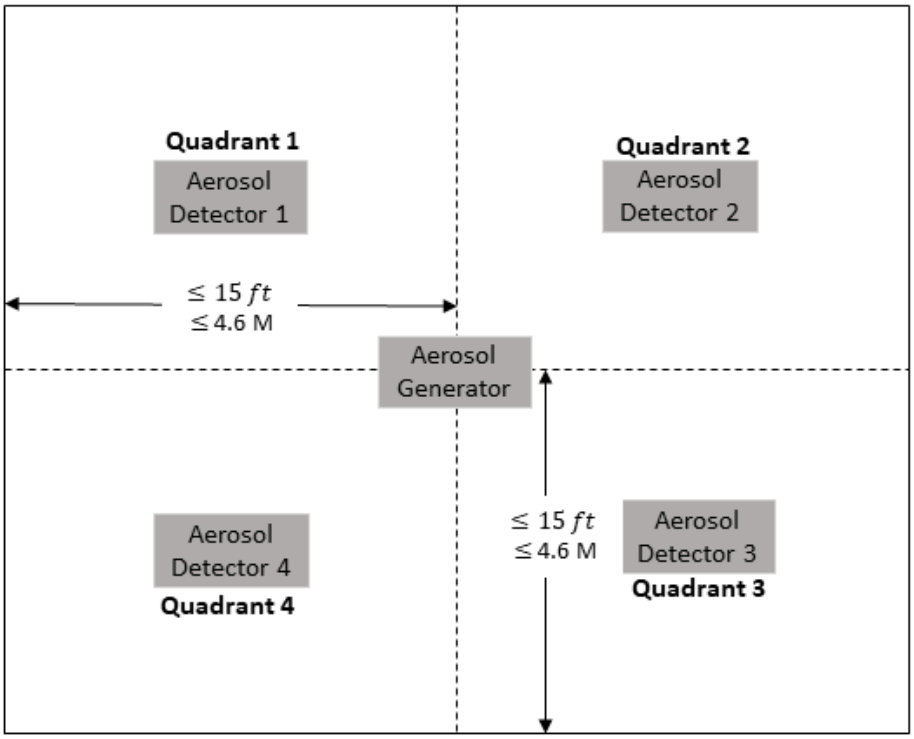

Figure C-1 Equipment configuration for determining ECAi of an occupied space.

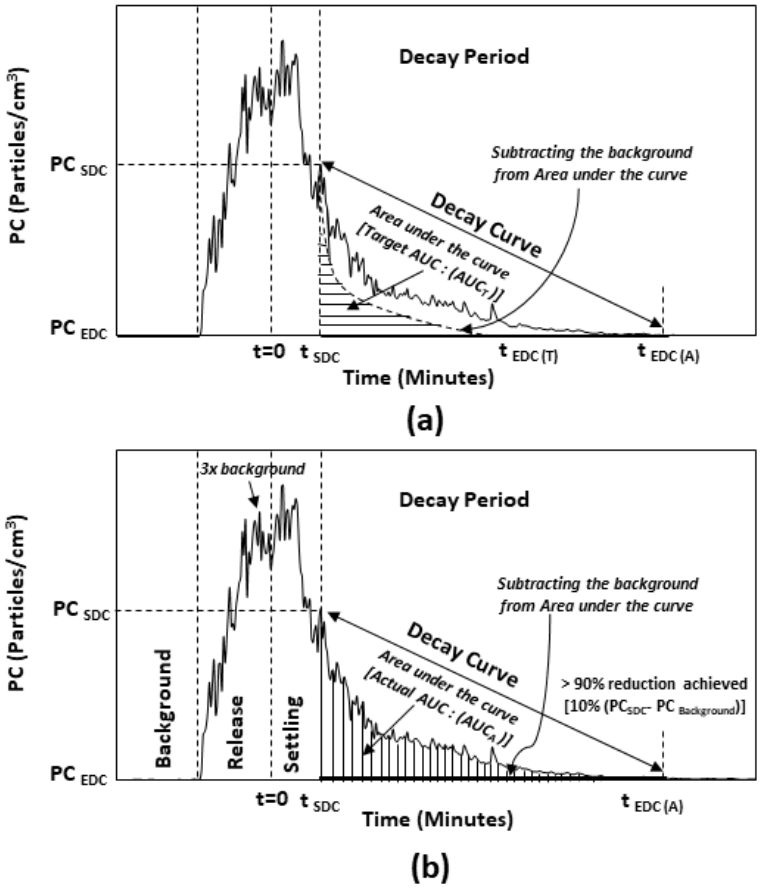

Figure C-2 Test periods for (a) target and (b) measured area under the curve.

d. **Decay period.** The period beginning when the settling period ends and ending after either $t = 60$ minutes or when 90% particle count reduction (which is 10% of [$PC_{SDC} - PC_{Background,En}$]) is reached, whichever comes first.
e. This method is valid for 0.35 to 12 air changes per hour (ach).

C4. ANALYSIS OF DATA

C4.1 Calculate the target volumetric airflow $V_{ECAi,ADn,T}$ for all aerosol detectors AD_n (n = 1 – 4+) using Equation C-1 and calculate the target air changes per hour (ACH_T) using Equation C-2.

$$V_{ECAi,\,ADn,\,T} = [(\text{ECAi} \times P_{Z,\,IRMM})] \tag{C-1}$$

$$\text{ACH}_{ADn,\,T} = \frac{(60 \times V_{ECAi,\,ADn,\,T})}{V} \tag{C-2}$$

where

$V_{ECAi,ADn,T}$ = target volumetric airflow per aerosol detector, 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 breathing zone in *IRMM* as defined in Section 5.1
V = volume of the space, ft^3 (m^3)
$ACH_{ADn,T}$ = target air changes per hour per aerosol detector, h^{-1}

C4.2 Calculate the global areas under the curve for target (AUC_T) and actual (AUC_A) as follows:

a. Background actual (calculated as the area under the curve using the average background value extrapolated over the decay period [t_{SDC} to $t_{EDC(A)}$])
b. Background target (calculated as the area under the curve using the average background value extrapolated over the target decay period [t_{SDC} to $t_{EDC(T)}$])
c. The decay period
   1. AUC_T shall be calculated as the area under the exponential decay curve defined by ACH_T from Equation C-2 from t_{SDC} to $t_{EDC(T)}$, minus background target.
   2. Calculate equation constant a using Equation C-3.

$$a = \frac{PC_{SDC}}{e^{-ACH_T \times t}} \tag{C-3}$$

   3. Calculate particle concentration (PC) associated with each time step using Equation C-4. The last time step is when either the calculated PC is reduced by 90% of the starting value minus the background [10% of ($PC_{SDC} - PC_{Background}$)] or t = 60 minutes.

$$PC = ae^{-ACH_T \times t} \tag{C-4}$$

   4. Calculate the area under the curve (Global AUC_T) using Equation C-5, or by integration between (t_{SDC}, PC_{SDC}) and ($t_{EDC(T)}$, PC_{EDC}).

$$\text{Global AUC}_T = \sum_{n=0}^{n = t_{EDC(T)}} \frac{(t_{n+1} - t_n)(PC_{n+1} + PC_n)}{2} - AUC_{B(T)} \tag{C-5}$$

   where

   t_{SDC} = time at the start of the decay curve, min
   PC_{SDC} = particle concentration at the start of the decay curve
   $t_{EDC(T)}$ = time at the end of the decay curve for the target decay curve, min
   PC_{EDC} = particle concentration at the end of the decay curve
   n = time steps from 0 to $t_{EDC(T)}$, min
   $AUC_{B(T)}$ = area under the curve for the background target

   5. The actual AUC_A (decay period AUC minus background actual):
      i. Calculate the area under the curve ($AUC_{A,ADn,En}$) for all aerosol detector for each size range using Equation C-6 between (t_{SDC}, PC_{SDC}) and ($t_{EDC(A)}$, PC_{EDC}).

$$\mathrm{AUC}_{A,\,ADn,\,En} = \sum_{n=0}^{n=t_{EDC(A)}} \frac{(t_{n+1}-t_n)(\mathrm{PC}_{n+1}+\mathrm{PC}_n)}{2} - \mathrm{AUC}_{B(A)} \qquad \text{(C-6)}$$

ii. Calculate the weighted average area under the curve using weights W_{E1}, W_{E2}, and W_{E3} from Section 7.4.1 for all aerosol detectors AD_n (n = 1 – 4+) using Equation C-7.

$$\mathrm{AUC}_{A,ADn,avg} = \mathrm{AUC}_{A,ADn,E1} \times \mathrm{W}_{E1} + \mathrm{AUC}_{A,ADn,E2} \times \mathrm{W}_{E2} + \mathrm{AUC}_{A,ADn,E3} \times \mathrm{W}_{E3} \qquad \text{(C-7)}$$

where

$\mathrm{AUC}_{A,ADn,avg}$ = area under the curve for the actual decay, aerosol detector n, averaged over all particle bins (E_1, E_2, E_3)

$\mathrm{AUC}_{A,ADn,E1}$ = area under the curve for the actual decay, aerosol detector n,$E1$

W_{E1} = particle size distribution weighting in the 0.3 to 1.0 micron range, %, from Section 7.4.1

$\mathrm{AUC}_{A,ADn,E2}$ = area under the curve for the actual decay, aerosol detector n,$E2$

W_{E2} = particle size distribution weighting in the 1.0 to 3.0 micron range, %, from Section 7.4.1

$\mathrm{AUC}_{A,ADn,E3}$ = area under the curve for the actual decay, aerosol detector n,$E3$

W_{E3} = particle size distribution weighting in the 3.0 to 10.0 micron range, %, from Section 7.4.1

iii. Calculate the global average (Global AUC_A) using Equation C-8:

$$\text{Global } \mathrm{AUC}_A = \frac{(\mathrm{AUC}_{A,\,AD1,\,avg} + \mathrm{AUC}_{A,\,AD2,\,avg} + \mathrm{AUC}_{A,\,AD3,\,avg})}{n} \qquad \text{(C-8)}$$

where

Global AUC_A = global average of the area under the curve for all aerosol detectors and size ranges E_1, E_2, and E_3

n = number of aerosol detectors in a test

C4.3 Calculate the actual volumetric airflow $V_{ECAi,ADn,En}$ for each aerosol detector and each E_1, E_2, and E_3 particle size range, using Equation C-9 [33].

$$V_{ECAi,\,ADn,\,En} = \frac{V_{ECAi,target} \times \text{Global } \mathrm{AUC}_T}{\mathrm{AUC}_{A,\,ADn,\,En}} \qquad \text{(C-9)}$$

where

$V_{ECAi,ADn,En}$ = volumetric airflow per aerosol detector, actual

$V_{ECAi,target}$ = volumetric airflow, target from Equation C-1

Global AUC_T = area under the curve, target from Equation C-5

$\mathrm{AUC}_{A,ADn,En}$ = area under the curve, actual from Equation C-6

C4.4 Calculate the actual weighted average, $V_{ECAi,ADn,avg,A}$ for each particle size bin, E_1, E_2, and E_3, and each aerosol detector using the weights W_{E1}, W_{E2}, and W_{E3} from Section 7.4.1 using Equation C-10.

Actual Weighted Average

$$V_{ECAi,ADn,avg,A} = V_{ECAi,ADn,E1,A} \times W_{E1} + V_{ECAi,ADn,E2,A} \times W_{E2} + V_{ECAi,ADn,E3,A} \times W_{E3} \qquad \text{(C-10)}$$

where

$V_{ECAi,ADn,avg,A}$ = actual volumetric airflow, aerosol detector n, averaged over all particle bins (E_1, E_2, E_3)

$V_{ECAi,ADn,E1,A}$ = particle size distribution weighting in the 0.3 to 1.0 micron range, %, from Section 7.4.1

W_{E1} = actual volumetric airflow, aerosol detector n,$E1$

$V_{ECAi,ADn,E2,A}$ = particle size distribution weighting in the 1.0 to 3.0 micron range, %, from Section 7.4.1

W_{E2} = actual volumetric airflow, aerosol detector n,$E2$

$V_{ECAi,ADn,E3,A}$ = particle size distribution weighting in the 3.0 to 10.0 micron range, %, from Section 7.4.1

W_{E3} = actual volumetric airflow, aerosol detector n,$E3$

C4.5 Calculate the target and actual global averages, $V_{ECAi,avg,T}$ and $V_{ECAi,avg,A}$, using the average of all the respective values of $V_{ECAi,ADn,T}$ and $V_{ECAi,ADn,avg,A}$ calculated for the space in Section C4.1 and Section C4.4 using Equation C-11 and Equation C-12.

Target Global Average

$$V_{ECAi,\,avg,\,T} = \frac{(V_{ECAi,\,AD1,\,T} + V_{ECAi,\,AD2,\,T} + V_{ECAi,\,AD3,\,T} + \ldots)}{n} \quad \text{(C-11)}$$

Actual Global Average

$$V_{ECAi,\,avg,\,A} = \frac{(V_{ECAi,\,AD1,\,avg,\,A} + V_{ECAi,\,AD2,\,avg,\,A} + V_{ECAi,\,AD3,\,avg,\,A} + \ldots)}{n} \quad \text{(C-12)}$$

where

$V_{ECAi,avg,T}$ = target global average volumetric airflow
n = total number of aerosol detectors
$V_{ECAi,avg,A}$ = actual global average volumetric airflow

C4.6 To determine the test outcome:

a. Pass: The actual global average $V_{ECAi,avg,A}$ shall be greater than or equal to the target global average $V_{ECAi,avg,T}$
b. Fail: The actual global average $V_{ECAi,avg,A}$ is less than the target global average $V_{ECAi,avg,T}$

C5. REPORTING

The test report shall include the following:

a. Test pass/fail outcome
b. The target and actual global averages ($V_{ECAi,avg,T}$, $V_{ECAi,avg,A}$)
c. The actual weighted average ($V_{ECAi,ADn,avg,A}$) for each aerosol detector, highlighting the minimum
d. The aerosol detector make, model, serial number, and date of last calibration
e. 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.
f. Test area location and equipment placement

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ASHRAE requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE.)

INFORMATIVE APPENDIX D

RISK ASSESSMENT MODEL FOR DETERMINATION OF MINIMUM EQUIVALENT CLEAN AIRFLOW RATES

Minimum *equivalent clean airflow* rates per person (ECAi) 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 ECAi that is necessary to keep the probability of infection low in each scenario for a high percentage of the time.

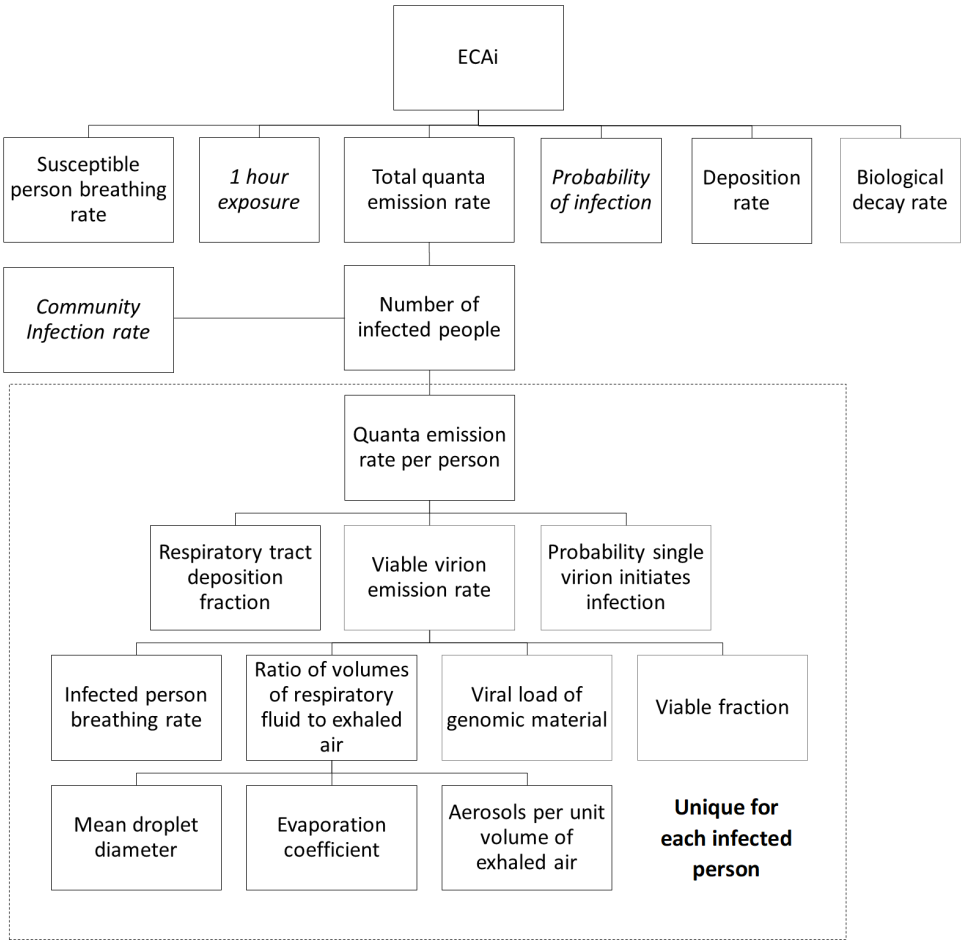

Figure D-1 Probabilistic model of infection ECAi. Variables may vary as a function of metabolic and respiratory activity. Dashed box shows variables unique for each infected person. Dotted boxes show biological terms specific to SARS-CoV-2. Italic text shows deterministic inputs. All other boxes are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

Figure D-1 shows the inputs and assumptions of the probabilistic model used to determine ECAi following Jones et al.[I2] and Iddon et al[I3]. 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.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ASHRAE requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE.)

INFORMATIVE APPENDIX E
BUILDING READINESS PLAN TEMPLATE

E1. BUILDING READINESS PLAN AND ASSESSMENT

ASHRAE Standard 241 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 HVAC and water building readiness assessment worksheet that can be used instead of a report.

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  - Filters 4
  - Air Cleaners—In HVAC 4
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Figure E-1 Sample table of contents for a building readiness plan.
(Courtesy of Hanson Professional Services, Inc.)

BUILDING READINESS ASSESSMENT — **Office Building**

Date Conducted — City, State

This is a sample Building Readiness Assessment worksheet prepared in September 2020 based on initial ASHRAE Epidemic Task Force Guidance. A similar worksheet, aligned with the requirements of Standard 241 Section 8.2.1 Existing Building Assessment, will be created by the Standard Project Committee.
The requirements and recommendations listed below are **NOT** for compliance with Standard 241.

Building Readiness Tasks	Level	Status	Details	Ref.
Ventilation				
Provide as much outside air as the HVAC system can accommodate while maintaining acceptable indoor conditions.	Baseline	In Place	Ventilation system provides outdoor air at its maximum capacity of 27 cfm/person (based on ASHRAE default occupant density), greater than 62.1 minimum standard.	1, 2
Disable demand-controlled ventilation.	Baseline	In Place	OA VAV boxes are providing maximum airflow; return air CO2 sensors are not being used to reduce airflow.	1
Limit occupancy in areas with inadequate ventilation.	Baseline	N/A		1
Assess Energy Recovery Ventilation systems for cross-contamination and adjust airflows as necessary.	Baseline	TBD	OAHU heat wheel seals have been inspected for wear; unit does not have a purge section. Confirm pressures higher on supply side relative to exhaust side.	2, 3
Ensure outdoor air intake has sufficient separation distance from contaminant sources (cooling tower, exhaust fan, pedestrian walkway, etc.).	Baseline	In Place		1
Filtration				
Use at least MERV-13 filters in all recirculating systems.	Baseline	In Place	Filters upgraded from MERV-13 to MERV-15.	1, 2, 4
Ensure good seal on filters (tape, gasket, sizing, etc.).	Baseline	In Place	Filters are taped at seams to minimize bypass of unfiltered air.	1, 2, 4
Use in-room HEPA filters in areas with limited system filtration capabilities.	Enhanced	Consider	Consider installing in-room HEPA filters in densely occupied spaces or spaces with higher risk activities; devices should produce no ozone.	1, 2, 4
Pressurization and Exhaust				
Resolve any significant building pressurization issues.	Baseline	N/A		1, 2
Provide negative pressure in each restroom using toilet exhaust system.	Baseline	In Place		1
Ensure that base building restrooms not connected to the central exhaust system have functioning exhaust and provide signage for occupant-controlled fans.	Baseline	N/A		1
Other HVAC Practices				
Identify any spaces with healthcare, high occupant density or vulnerable populations; create plan for additional measures (portable HEPA filters, upper room UVGI).	Baseline	Action Required	Fitness centers and conference centers can be high-risk spaces. Create plan to mitigate risk in these spaces prior to re-entry.	1, 2, 4
Communicate with tenants regarding risk mitigation for tenant owned and operated HVAC equipment.	Baseline	In Place	Ground floor retail tenants: recommend adopting HVAC risk mitigation practices for ventilation, filtration, and restroom exhaust.	

Reference Materials

1. ASHRAE Epidemic Task Force - Commercial Buildings Guidance (8/17/2020)
2. ASHRAE Epidemic Task Force - Building Readiness (8/19/2020)
3. ASHRAE Epidemic Operation of Energy Recovery Ventilation Systems (6/9/2020)
4. ASHRAE Epidemic Task Force - Filtration & Disinfection (8/7/2020)

Figure E-2 Sample HVAC and water building readiness assessment worksheet.
(Courtesy of Servidyne.)

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ASHRAE requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE.)

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 ASHRAE Standard 241.

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 at **www.ashrae.org/241-2023**. Figure F-1 and Figure F-2 show a preview of the calculator instructions and interface, respectively.

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

Figure F-1 Equivalent Clean Airflow Calculator instructions.

Phase of the Process		**Assessment**	**Planning**	**Planning**	**Planning**	**Planning**	**Implement**
Name of Space / AHU / Building	**Units**	**EXISTING**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**FINAL SYSTEM**
Description of system or Option		AHU with X,Y,Z	Description	Description	Description	Description	**Description**
Space Type from Standard 241	Type	Office	Office	Office	Office	Office	Office
Target ECAi from Standard 241 (See Instructions for Table)	CFM / Person	30	30	30	30	30	40.0
Area	Sq Ft	2,000	2,000	2,000	2,000	2,000	2,400
Average Ceiling Height	Ft	9	9	9	9	9	**9**
Volume	Cu Ft	18,000	18,000	18,000	18,000	18,000	**21600**
Total Supply Air	CFM	1,800	1,800	1,800	1,800	1,800	**1800**
Total Outdoor Air	CFM	240	240	240	240	240	**272**
Occupancy - Design (Pz)	Quantity	12	12	12	12	12	**12**
Occupancy - IRMM Target ($Pz_{,IRMM}$)	Quantity	8	8	8	8	8	**12**
$V_{ECAi,t,Des}$ Airflow Target - Design Occupancy	CFM	360	360	360	360	360	**480**
$V_{ECAi,t,IRMM}$ Airflow Target - IRMM Target Occ.	CFM	240	240	240	240	240	**480**
Central AHU Filter MERV Rating	MERV	12	13	13	13	13	**13**
Method for Rating Filter	241 or DNFE	241	241	DNFE	241	241	**241**
Filter Pathogen Removal Efficiency	εPR	71.0%	77.0%	67.0%	77.0%	77.0%	77.0%
UV in HVAC - Single Pass Inactivation	%	0.0%	35.00%	50.00%	0.00%	0.00%	**0.00%**
Air Treatment in HVAC (Impacts Space)	CFM	400	100	0	0	0	**0**
Air Treatment Device in Space	CADR	0	4	0	0	0	**0**
Number of Air Treatment Devices in Space	Quantity	0	1	0	0	0	**0**

Figure F-2 Equivalent Clean Airflow Calculator interface.

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

ASHRAE's 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 Ventilations 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 at **www.ashrae.org/241-2023**.

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INFORMATIVE APPENDIX H
EXHAUST RE-ENTRAINMENT GUIDE

ASHRAE's Epidemic Task Force 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

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POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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