



# STANDARD

**ANSI/ASHRAE Standard 62.1-2016**

(Supersedes ANSI/ASHRAE Standard 62.1-2013)

Includes ANSI/ASHRAE addenda listed in Appendix K

# Ventilation for Acceptable Indoor Air Quality

See Appendix K for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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**CONTENTS**  
**ANSI/ASHRAE Standard 62.1-2016,**  
**Ventilation for Acceptable Indoor Air Quality**

<b>SECTION</b>	<b>PAGE</b>
Foreword .....	2
1 Purpose .....	2
2 Scope .....	3
3 Definitions .....	3
4 Outdoor Air Quality .....	5
5 Systems and Equipment .....	5
6 Procedures .....	11
7 Construction and System Start-Up .....	19
8 Operations and Maintenance .....	21
9 References .....	21
Normative Appendix A: Multiple-Zone Systems .....	24
Normative Appendix B: Separation of Exhaust Outlets and Outdoor Air Intakes .....	27
Informative Appendix C: Summary of Selected Air Quality Guidelines .....	29
Informative Appendix D: Rationale for Minimum Physiological Requirements for Respiration Air Based on CO <sub>2</sub> Concentration .....	40
Informative Appendix E: Acceptable Mass Balance Equations for Use with the IAQ Procedure .....	42
Informative Appendix F: Information on Selected National Standards and Guidelines for PM <sub>10</sub> , PM <sub>2.5</sub> , and Ozone .....	44
Informative Appendix G: Application and Compliance .....	45
Informative Appendix H: Documentation .....	47
Informative Appendix I: National Ambient Air Quality Standards (NAAQS) .....	50
Informative Appendix J: Informative References .....	51
Informative Appendix K: Addenda Description Information .....	52

**NOTE**

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## FOREWORD

The 2016 edition of ANSI/ASHRAE Standard 62.1-2016 combines Standard 62.1-2013 and the fourteen approved and published addenda to the 2013 edition. Specific information on the contents of each addendum and approval dates for addenda are included in Informative Appendix K.

First published in 1973 as Standard 62, Standard 62.1 is updated on a regular basis using ASHRAE's continuous maintenance procedures. Addenda are publicly reviewed, approved by ASHRAE and ANSI, and published as a supplement at approximately 18 months. The complete collection of addenda to the standard are incorporated into the current edition and published as a new edition every three years.

Standard 62.1 has undergone key changes over the years, reflecting the ever-expanding body of knowledge, experience, and research related to ventilation and air quality. While the purpose of the standard remains unchanged—to specify minimum ventilation rates and other measures intended to provide indoor air quality (IAQ) that is acceptable to human occupants and that minimizes adverse health effects—the means of achieving this goal have evolved. In its first edition, the standard adopted a prescriptive approach to ventilation by specifying both minimum and recommended outdoor airflow rates to obtain acceptable indoor air quality for a variety of indoor spaces. In its 1981 edition, the standard reduced minimum outdoor airflow rates and introduced an alternative performance-based approach, the Indoor Air Quality Procedure, which allowed for the calculation of the amount of outdoor air necessary to maintain the levels of indoor air contaminants below recommended limits. Today, the standard includes three procedures for ventilation design, the IAQ Procedure, the Ventilation Rate Procedure, and the Natural Ventilation Procedure.

In its 1989 edition, in response to a growing number of buildings with apparent indoor air quality problems, the standard increased minimum outdoor airflow rates significantly and introduced a requirement for finding outdoor air intake flow requirements for multiple-zone recirculating systems.

The 1999 and 2001 editions made several minor changes and clarifications that did not impact the minimum required outdoor airflow rates. The 2004 edition—the last time the standard was revised in its entirety—modified the IAQ Procedure to improve enforceability, but more significantly it modified the Ventilation Rate Procedure, changing both the minimum outdoor airflow rates and the procedures for calculating both zone-level and system-level outdoor airflow rates. The 2007, 2010, and 2013 editions of the standard provided

some significant updates, but the changes primarily focused on usability and clarity.

The 2016 edition revises and improves the standard in several ways. Scope was changed to remove residential occupancies from 62.1 with a concurrent change in 62.2 to add all residential spaces. Significant changes include the following:

- Previously, Standard 62.1 had responsibility for multi-family residential buildings that are 4 stories or more. Now the dwelling units themselves are covered by Standard 62.2 regardless of building height, while common areas are covered by Standard 62.1.
- The definition of “environmental tobacco smoke” (ETS) was revised to include emissions from electronic smoking devices and from smoking of cannabis.
- Operations and maintenance requirements were revised to closer align with the requirements in ASHRAE/ACCA Standard 180-2012.
- Requirements were added to the Indoor Air Quality Procedure for determining minimum ventilation rates by including consideration of the combined effects of multiple contaminants of concern on individual organ systems.
- Laboratory exhaust continues to be assigned a default of Air Class 4, but the change explicitly allows a responsible EH&S professional to determine that a lower air class is appropriate for particular systems.
- Ventilation is allowed to be reduced to zero through the use of occupancy sensors (not through contaminant or CO<sub>2</sub> measurements) for spaces of selected occupancy types, provided that ventilation is restored to  $V_{bz}$  whenever occupancy is detected.
- Changes in language related to demand control ventilation remove the assumption that the standard is intended to be used only for calculations for code review and not physical operation.

For more specific information on these changes and on other revisions made to the standard by other addenda, refer to Informative Appendix K. Users of the standard are encouraged to use the continuous maintenance procedure to suggest changes for further improvements.

A form for submitting change proposals is included in the back of the standard. The project committee for Standard 62.1 will take formal action on all change proposals received.

## 1. PURPOSE

**1.1** The purpose of this standard is to specify minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects.

**1.2** This standard is intended for regulatory application to new buildings, additions to existing buildings, and those changes to existing buildings that are identified in the body of the standard.

**1.3** This standard is intended to be used to guide the improvement of indoor air quality in existing buildings.

## 2. SCOPE

**2.1** This standard applies to spaces intended for human occupancy within buildings except those within dwelling units in residential occupancies in which occupants are nontransient.

**2.2** This standard defines requirements for ventilation and air-cleaning-system design, installation, commissioning, and operation and maintenance.

**2.3** Additional requirements for laboratory, industrial, health care, and other spaces may be dictated by workplace and other standards, as well as by the processes occurring within the space.

**2.4** Although the standard may be applied to both new and existing buildings, the provisions of this standard are not intended to be applied retroactively when the standard is used as a mandatory regulation or code.

**2.5** This standard does not prescribe specific ventilation rate requirements for spaces that contain smoking or that do not meet the requirements in the standard for separation from spaces that contain smoking.

**2.6** Ventilation requirements of this standard are based on chemical, physical, and biological contaminants that can affect air quality.

**2.7** Consideration or control of thermal comfort is not included.

**2.8** This standard contains requirements, in addition to ventilation, related to certain sources, including outdoor air, construction processes, moisture, and biological growth.

**2.9** Acceptable indoor air quality may not be achieved in all buildings meeting the requirements of this standard for one or more of the following reasons:

- a. Because of the diversity of sources and contaminants in indoor air
- b. Because of the many other factors that may affect occupant perception and acceptance of indoor air quality, such as air temperature, humidity, noise, lighting, and psychological stress
- c. Because of the range of susceptibility in the population
- d. Because outdoor air brought into the building may be unacceptable or may not be adequately cleaned

## 3. DEFINITIONS (SEE FIGURE 3.1)

**acceptable indoor air quality:** air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

**air-cleaning system:** a device or combination of devices applied to reduce the concentration of airborne contaminants such as microorganisms, dusts, fumes, respirable particles, other particulate matter, gases, vapors, or any combination thereof.

**air conditioning:** the process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness, and distribution.

**air, ambient:** the air surrounding a building; the source of outdoor air brought into a building.

**air, exhaust:** air removed from a space and discharged to outside the building by means of mechanical or natural ventilation systems.

**air, indoor:** the air in an enclosed occupiable space.

**air, makeup:** any combination of outdoor and transfer air intended to replace exhaust air and exfiltration.

**air, outdoor:** ambient air and ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation, or by infiltration.

**air, primary:** air supplied to the ventilation zone prior to mixing with any locally recirculated air.

**air, recirculated:** air removed from a space and reused as supply air.

**air, return:** air removed from a space to be recirculated or exhausted.

**air, supply:** air delivered by mechanical or natural ventilation to a space and composed of any combination of outdoor air, recirculated air, or transfer air.

**air, transfer:** air moved from one indoor space to another.

**air, ventilation:** that portion of supply air that is outdoor air plus any recirculated air that has been treated for the purpose of maintaining acceptable indoor air quality.

**breathing zone:** the region within an occupied 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.

**cognizant authority:** an agency or organization that has the expertise and jurisdiction to establish and regulate concentration limits for airborne contaminants, or an agency or organization that is recognized as authoritative and has the scope and expertise to establish guidelines, limit values, or concentrations levels for airborne contaminants.

**concentration:** the quantity of one constituent dispersed in a defined amount of another.

**conditioned space:** that part of a building that is heated or cooled, or both, for the comfort of occupants.

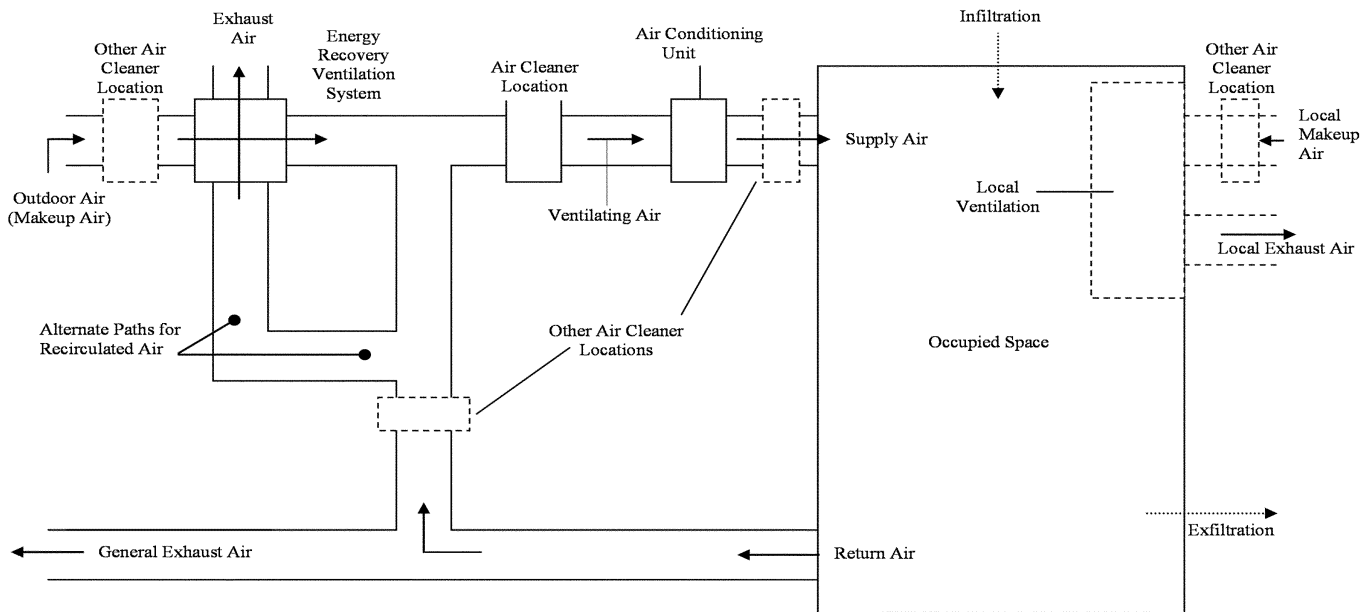
**contaminant:** an unwanted airborne constituent with the potential to reduce acceptability of the air.

**contaminant mixture:** two or more contaminants that target the same organ system.

**demand-controlled ventilation (DCV):** any means by which the breathing zone outdoor airflow ( $V_{bz}$ ) can be varied to the occupied space or spaces based on the actual or estimated number of occupants, ventilation requirements of the occupied zone, or both.

**dwelling unit:** a single unit providing complete, independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

**energy recovery ventilation system:** a device or combination of devices applied to provide the outdoor air for ventilation in which energy is transferred between the intake and exhaust airstreams.



**FIGURE 3.1** Ventilation system.

**environmental tobacco smoke (ETS):** the “aged” and diluted combination of both side-stream smoke (smoke from the lit end of a cigarette or other tobacco product) and exhaled mainstream smoke (smoke that is exhaled by a smoker). ETS is commonly referred to as *secondhand smoke*. This definition includes smoke produced from the combustion of cannabis and controlled substances and the emissions produced by electronic smoking devices.

**equipment well:** an area (typically on the roof) enclosed on three or four sides by walls that are less than 75% free area, and the lesser of the length and width of the enclosure is less than three times the average height of the walls. The free area of the wall is the ratio of area of the openings through the wall, such as openings between louver blades and undercuts, divided by the gross area (length times height) of the wall.

**ETS-free area:** an area where no smoking occurs that is separated from ETS areas according to the requirements of this standard.

**Informative Note:** A no-smoking area is not necessarily an ETS-free area.

**ETS area:** spaces where smoking is permitted, as well as those not separated from spaces where smoking is permitted in accord with the requirements of Section 5 in this standard.

**exfiltration:** uncontrolled outward air leakage from conditioned spaces through unintentional openings in ceilings, floors, and walls to unconditioned spaces or the outdoors caused by pressure differences across these openings due to wind, inside-outside temperature differences (stack effect), and imbalances between outdoor and exhaust airflow rates.

**industrial space:** an indoor environment where the primary activity is production or manufacturing processes.

**infiltration:** uncontrolled inward air leakage to conditioned spaces through unintentional openings in ceilings, floors, and

walls from unconditioned spaces or the outdoors caused by the same pressure differences that induce exfiltration.

**mechanical ventilation:** ventilation provided by mechanically powered equipment such as motor-driven fans and blowers but not by devices such as wind-driven turbine ventilators and mechanically operated windows.

**microorganism:** a microscopic organism, especially a bacterium, fungus, or protozoan.

**natural ventilation:** ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building.

**net occupiable area:** the floor area of an occupiable space defined by the inside surfaces of its walls but excluding shafts, column enclosures, and other permanently enclosed, inaccessible, and unoccupiable areas. Obstructions in the space, such as furnishings, display or storage racks, and other obstructions, whether temporary or permanent, are considered to be part of the net occupiable area.

**nontransient:** occupancy of a dwelling unit or sleeping unit for more than 30 days.

**occupant sensor:** a device such as a motion detector or a captive key system that detects the presence of one or more persons within a space.

**occupiable space:** an enclosed space intended for human activities, excluding those spaces that are intended primarily for other purposes, such as storage rooms and equipment rooms, and that are only occupied occasionally and for short periods of time.

**occupied mode:** when a zone is scheduled to be occupied.

**occupied-standby mode:** when a zone is scheduled to be occupied and an occupant sensor indicates zero population within the zone.

**odor:** a quality of gases, liquids, or particles that stimulates the olfactory organ.

**readily accessible:** capable of being reached quickly for operation without requiring personnel to climb over or remove obstacles or to resort to the use of unsafe climbing aids such as tables or chairs.

**residential occupancies:** occupancies that are not classified as institutional by the authority having jurisdiction and that contain permanent provisions for sleeping.

**sleeping unit:** a room or space in which people sleep that includes permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a dwelling unit are not sleeping units.

**unoccupied mode:** when a zone is not scheduled to be occupied.

**ventilation:** the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space.

**ventilation zone:** any indoor area that requires ventilation and comprises one or more spaces with the same occupancy category (see Table 6.2.2.1), occupant density, zone air distribution effectiveness (see Section 6.2.2.2), and design zone primary airflow (see Section 6.2.5.1) per unit area.

**Informative Note:** A ventilation zone is not necessarily an independent thermal control zone; however, spaces that can be combined for load calculation purposes can often be combined into a single zone for ventilation calculations purposes.

**volume, space:** the total volume of an occupiable space enclosed by the building envelope, plus that of any spaces permanently open to the occupiable space, such as a ceiling attic used as a ceiling return plenum.

## 4. OUTDOOR AIR QUALITY

Outdoor air quality shall be investigated in accordance with Sections 4.1 and 4.2 prior to completion of ventilation system design. The results of this investigation shall be documented in accordance with Section 4.3.

**4.1 Regional Air Quality.** The status of compliance with national ambient air quality standards shall be determined for the geographic area of the building site.

**4.1.1** In the United States, compliance status shall be either in “attainment” or “nonattainment” with the *National Ambient Air Quality Standards* (NAAQS)<sup>1</sup>. In the United States, areas with no U.S. Environmental Protection Agency (USEPA) compliance status designation shall be considered “attainment” areas.

**Informative Note:** The NAAQS are shown in Table I-1 of Informative Appendix I.

**4.2 Local Air Quality.** An observational survey of the building site and its immediate surroundings shall be conducted during hours the building is expected to be normally occupied

to identify local contaminants from surrounding facilities that will be of concern if allowed to enter the building.

**4.3 Documentation.** Documentation of the outdoor air quality investigation shall be reviewed with building owners or their representative and shall include the following as a minimum:

a. Regional air quality compliance status

**Informative Note to 4.3(a):** Regional outdoor air quality compliance status for the United States is available from USEPA located at [www.epa.gov](http://www.epa.gov).

b. Local survey information

1. Date of observations
2. Time of observations
3. Site description
4. Description of facilities on site and on adjoining properties
5. Observation of odors or irritants
6. Observation of visible plumes or visible air contaminants
7. Description of sources of vehicle exhaust on site and on adjoining properties
8. Identification of potential contaminant sources on the site and from adjoining properties, including any that operate only seasonally

c. Conclusion regarding the acceptability of outdoor air quality and the information supporting the conclusion

## 5. SYSTEMS AND EQUIPMENT

**5.1 Ventilation Air Distribution.** Ventilating systems shall be designed in accordance with the requirements of the following subsections.

**5.1.1 Designing for Air Balancing.** The ventilation air distribution system shall be provided with means to adjust the system to achieve at least the minimum ventilation airflow as required by Section 6 under any load condition.

**5.1.2 Plenum Systems.** When the ceiling or floor plenum is used both to recirculate return air and to distribute ventilation air to ceiling-mounted or floor-mounted terminal units, the system shall be engineered such that each space is provided with its required minimum ventilation airflow.

**Informative Note:** Systems with direct connection of ventilation air ducts to terminal units, for example, comply with this requirement.

**5.1.3 Documentation.** The design documents shall specify minimum requirements for air balance testing or reference applicable national standards for measuring and balancing airflow. The design documentation shall state assumptions that were made in the design with respect to ventilation rates and air distribution.

### 5.2 Exhaust Duct Location

**5.2.1** Exhaust ducts that convey Class 4 air shall be negatively pressurized relative to ducts, plenums, or occupiable spaces through which the ducts pass.

**5.2.2** Exhaust ducts under positive pressure that convey Class 2 or Class 3 air shall not extend through ducts, plenums,

**TABLE 5.5.1 Air Intake Minimum Separation Distance**

Object	Minimum Distance, ft (m)
Class 2 air exhaust/relief outlet <sup>a</sup>	10 (3)
Class 3 air exhaust/relief outlet <sup>a</sup>	15 (5)
Class 4 air exhaust/relief outlet <sup>b</sup>	30 (10)
Plumbing vents terminating less than 3 ft (1 m) above the level of the outdoor air intake	10 (3)
Plumbing vents terminating at least 3 ft (1 m) above the level of the outdoor air intake	3 (1)
Vents, chimneys, and flues from combustion appliances and equipment <sup>c</sup>	15 (5)
Garage entry, automobile loading area, or drive-in queue <sup>d</sup>	15 (5)
Truck loading area or dock, bus parking/idling area <sup>d</sup>	25 (7.5)
Driveway, street, or parking place <sup>d</sup>	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake <sup>e,f</sup>	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

a. This requirement applies to the distance from the outdoor air intakes for one ventilation system to the exhaust outlets and relief outlets for any other ventilation system.

b. Minimum distance listed does not apply to laboratory fume hood exhaust air outlets. Separation criteria for fume hood exhaust shall be in compliance with ANSI/AIHA Z9.5 <sup>6</sup>. Informative Appendix J contains sources of additional information on separation criteria. These include the *ACGIH Industrial Ventilation Manual* <sup>11</sup>, *ASHRAE Handbook—HVAC Applications* <sup>12</sup>, *ASHRAE Laboratory Design Guide* <sup>13</sup>, and NSF/ANSI 49 <sup>14</sup>.

c. The minimum distances relative to fuel-fired appliances shall be as required by ANSI Z223.1/NFPA 54 <sup>7</sup> for fuel gas burning appliances and equipment, NFPA 31 <sup>8</sup> for oil burning appliances and equipment, and NFPA 211 <sup>9</sup> for other combustion appliances and equipment.

d. Distance measured to closest place that vehicle exhaust is likely to be located

e. The minimum separation distance shall not apply where outdoor surfaces below the air intake are sloped more than 45 degrees from horizontal or where such surfaces are less than 1 in. (30 mm) in width.

f. Where snow accumulation is expected, the surface of the snow at the expected average snow depth shall be considered to be a surface directly below an intake.

or occupiable spaces other than the space from which the exhaust air is drawn.

**Exception:** Exhaust ducts conveying Class 2 air and exhaust ducts conveying air from residential kitchen hoods that are sealed in accordance with SMACNA Seal Class A <sup>2</sup>.

**5.3 Ventilation System Controls.** Mechanical ventilation systems shall include controls in accordance with the following subsections.

**5.3.1** All systems shall be provided with manual or automatic controls to maintain not less than the outdoor air intake flow ( $V_{ot}$ ) required by Section 6 under all load conditions or dynamic reset conditions.

**5.3.2** Systems with fans supplying variable primary air ( $V_{ps}$ ), including single-zone VAV and multiple-zone recirculating VAV systems, shall be provided with one or more of the following:

- Outdoor air intake, return air dampers, or a combination of the two that modulates to maintain not less than the outdoor air intake flow ( $V_{ot}$ )
- Outdoor air injection fans that modulate to maintain not less than the outdoor air intake flow ( $V_{ot}$ )
- Other means of ensuring compliance with Section 5.3.1

**5.4 Airstream Surfaces.** All airstream surfaces in equipment and ducts in the heating, ventilating, and air-conditioning system shall be designed and constructed in accordance with the requirements of the following subsections.

**5.4.1 Resistance to Mold Growth.** Material surfaces shall be determined to be resistant to mold growth in accordance with a standardized test method, such as the Mold Growth and Humidity Test in UL 181 <sup>3</sup>, ASTM C 1338 <sup>4</sup>, or ASTM D3273 <sup>5</sup>.

**Exception:** Sheet metal surfaces and metal fasteners.

**Informative Note:** Even with this resistance, any airstream surface that is continuously wetted is still subject to microbial growth.

**5.4.2 Resistance to Erosion.** Airstream surface materials shall be evaluated in accordance with the Erosion Test in UL 181 <sup>3</sup> and shall not break away, crack, peel, flake off, or show evidence of delamination or continued erosion under test conditions.

**Exception:** Sheet metal surfaces and metal fasteners.

**5.5 Outdoor Air Intakes.** Ventilation system outdoor intakes shall be designed in accordance with the following subsections.

**5.5.1 Location.** Outdoor air intakes (including openings that are required as part of a natural ventilation system) shall be located such that the shortest distance from the intake to any specific potential outdoor contaminant source shall be equal to or greater than the separation distance listed in Table 5.5.1 or the calculation method in Normative Appendix B.

**Exception:** Other separation distances shall be permitted, provided it can be shown analytically that an equivalent



or lesser rate of introduction of contaminants from outdoor sources will be attained.

**5.5.2 Rain Entrainment.** Outdoor air intakes that are part of the mechanical ventilation system shall be designed to manage rain entrainment in accordance with one or more of the following:

- a. Limit water penetration through the intake to 0.07 oz/ft<sup>2</sup>·h (21.5 g/m<sup>2</sup>·h) of inlet area when tested using the rain test apparatus described in Section 58 of UL 1995<sup>10</sup>.
  - b. Select louvers that limit water penetration to a maximum of 0.01 oz/ft<sup>2</sup> (3 g/m<sup>2</sup>) of louver free area at the maximum intake velocity. This water penetration rate shall be determined for a minimum 15-minute test duration when subjected to a water flow rate of 0.25 gal/min (16 mL/s) as described under the water penetration test in AMCA 500-L<sup>11</sup> or equivalent. Manage the water that penetrates the louver by providing a drainage area or moisture removal devices.
  - c. Select louvers that restrict wind-driven rain penetration to less than 2.36 oz/ft<sup>2</sup>·h (721 g/m<sup>2</sup>·h) when subjected to a simulated rainfall of 3 in. (75 mm) per hour and a 29 mph (13 m/s) wind velocity at the design outdoor air intake rate with the air velocity calculated based on the louver face area.
- Informative Note to 5.5.2(c):** This performance corresponds to Class A (99% effectiveness) when rated according to AMCA 511<sup>15</sup> and tested per AMCA 500-L<sup>16</sup>.
- d. Use rain hoods sized for no more than 500 fpm (2.5 m/s) face velocity with a downward-facing intake such that all intake air passes upward through a horizontal plane that intersects the solid surfaces of the hood before entering the system.
  - e. Manage the water that penetrates the intake opening by providing a drainage area or moisture removal devices.

**5.5.3 Rain Intrusion.** Air-handling and distribution equipment mounted outdoors shall be designed to prevent rain intrusion into the airstream when tested at design airflow and with no airflow, using the rain test apparatus described in Section 58 of UL 1995<sup>10</sup>.

**5.5.4 Snow Entrainment.** Where climate dictates, outdoor air intakes that are part of the mechanical ventilation system shall be designed as follows to manage water from snow that is blown or drawn into the system:

- a. Access doors to permit cleaning of wetted surfaces shall be provided.
- b. Outdoor air ductwork or plenums shall pitch to drains designed in accordance with the requirements of Section 5.10.

**5.5.5 Bird Screens.** Outdoor air intakes shall include a screening device designed to prevent penetration by a 0.5 in. (13 mm) diameter probe. The screening device material shall be corrosion resistant. The screening device shall be located, or other measures shall be taken, to prevent bird nesting within the outdoor air intake.

**Informative Note:** Any horizontal surface may be subject to bird nesting.

**5.6 Local Capture of Contaminants.** The discharge from noncombustion equipment that captures the contaminants generated by the equipment shall be ducted directly to the outdoors.

**Exception:** Equipment specifically designed for discharge indoors in accordance with the manufacturer's recommendations.

**5.7 Combustion Air.** Fuel-burning appliances, both vented and unvented, shall be provided with air for combustion and removal of combustion products in accordance with manufacturer instructions. Products of combustion from vented appliances shall be vented directly outdoors.

**5.8 Particulate Matter Removal.** Particulate matter filters or air cleaners having a minimum efficiency reporting value (MERV) of not less than 8 when rated in accordance with ANSI/ASHRAE Standard 52.2<sup>12</sup> shall be provided upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space.

**Exception:** Cooling coils that are designed, controlled, and operated to provide sensible cooling only.

**5.9 Dehumidification Systems.** Mechanical air-conditioning systems with dehumidification capability shall be designed to comply with the following subsections.

**5.9.1 Relative Humidity.** Occupied-space relative humidity shall be limited to 65% or less when system performance is analyzed with outdoor air at the dehumidification design condition (that is, design dew-point and mean coincident dry-bulb temperatures) and with the space interior loads (both sensible and latent) at cooling design values and space solar loads at zero.

**Exception:** Spaces where process or occupancy requirements dictate higher humidity conditions, such as kitchens; hot-tub rooms that contain heated standing water; refrigerated or frozen storage rooms and ice rinks; and spaces designed and constructed to manage moisture, such as shower rooms, pool rooms, and spa rooms.

**Informative Note:** System configuration, climatic conditions, or a combination of both might adequately limit space relative humidity at these conditions without additional humidity-control devices. The specified conditions challenge the system dehumidification performance with high outdoor latent load and low space sensible heat ratio.

**5.9.2 Building Exfiltration.** Ventilation systems for a building shall be designed such that the total building outdoor air intake equals or exceeds the total building exhaust under all load and dynamic reset conditions.

**Exceptions:**

1. Where an imbalance is required by process considerations and approved by the authority having jurisdiction, such as in certain industrial facilities.
2. When outdoor air dry-bulb temperature is below the indoor space dew-point design temperature.

**Informative Note:** Although individual zones within a building may be neutral or negative with respect to outdoors

or to other zones, net positive mechanical intake airflow for the building as a whole reduces infiltration of untreated outdoor air.

**5.10 Drain Pans.** Drain pans, including their outlets and seals, shall be designed and constructed in accordance with this section.

**5.10.1 Drain Pan Slope.** Pans intended to collect and drain liquid water shall be sloped at least 0.125 in./ft (10 mm/m) from the horizontal toward the drain outlet or shall be otherwise designed such that water drains freely from the pan whether the fan is ON or OFF.

**5.10.2 Drain Outlet.** The drain pan outlet shall be located at the lowest point(s) of the drain pan and shall be sized to preclude drain pan overflow under any normally expected operating condition.

**5.10.3 Drain Seal.** For configurations that result in negative static pressure at the drain pan relative to the drain outlet (such as a draw-through unit), the drain line shall include a P-trap or other sealing device designed to maintain a seal against ingestion of ambient air while allowing complete drainage of the drain pan under any normally expected operating condition, whether the fan is ON or OFF.

**5.10.4 Pan Size.** The drain pan shall be located under the water-producing device. Drain pan width shall be sized to collect water droplets across the entire width of the water-producing device or assembly. For horizontal airflow configurations, the drain pan length shall begin at the leading face or edge of the water-producing device or assembly and extend downstream from the leaving face or edge to a distance of either

- a. one half of the installed vertical dimension of the water-producing device or assembly or
- b. as necessary to limit water droplet carryover beyond the drain pan to 0.0044 oz/ ft<sup>2</sup> (1.5 mL/m<sup>2</sup>) of face area per hour under peak sensible and peak dew-point design conditions, accounting for both latent load and coil face velocity.

## **5.11 Finned-Tube Coils and Heat Exchangers**

**5.11.1 Drain Pans.** A drain pan in accordance with Section 5.10 shall be provided beneath all dehumidifying cooling coil assemblies and all condensate-producing heat exchangers.

**5.11.2 Finned-Tube Coil Selection for Cleaning.** Individual finned-tube coils or multiple finned-tube coils in series without intervening access spaces of at least 18 in. (457 mm) shall be selected to result in no more than 0.75 in. wc (187 Pa) combined dry-coil pressure drop at 500 fpm (2.54 m/s) face velocity.

**5.12 Humidifiers and Water-Spray Systems.** Steam and direct-evaporative humidifiers, air washers, direct-evaporative coolers, and other water-spray systems shall be designed in accordance with this section.

**5.12.1 Water Quality.** Water purity shall meet or exceed potable water standards at the point where it enters the ventilation system, space, or water-vapor generator. Water vapor generated shall contain no chemical additives other than those chemicals in a potable water system.

## **Exceptions:**

1. Water-spray systems that utilize chemical additives that meet NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals—Health Effects*<sup>13</sup>.
2. Boiler water additives that meet the requirements of 21 CFR 173.310, *Secondary Direct Food Additives Permitted In Food For Human Consumption*<sup>14</sup>, and include automated dosing devices.

**5.12.2 Obstructions.** Air cleaners or ductwork obstructions, such as turning vanes, volume dampers, and duct offsets greater than 15 degrees, that are installed downstream of humidifiers or water spray systems shall be located a distance equal to or greater than the absorption distance recommended by the humidifier or water-spray system manufacturer.

**Exception:** Equipment such as eliminators, coils, or evaporative media shall be permitted to be located within the absorption distance recommended by the manufacturer, provided a drain pan complying with the requirements of Section 5.10 is used to capture and remove any water that drops out of the airstream due to impingement on these obstructions.

## **5.13 Access for Inspection, Cleaning, and Maintenance**

**5.13.1 Equipment Clearance.** Ventilation equipment shall be installed with working space that will allow for inspection and routine maintenance, including filter replacement and fan belt adjustment and replacement.

**5.13.2 Ventilation Equipment Access.** Access doors, panels, or other means shall be provided and sized to allow unobstructed access for inspection, maintenance, and calibration of all ventilation system components for which routine inspection, maintenance, or calibration is necessary. Ventilation system components include air-handling units, fan-coil units, water-source heat pumps, other terminal units, controllers, and sensors.

**5.13.3 Air Distribution System.** Access doors, panels, or other means shall be provided in ventilation equipment, ductwork, and plenums, located and sized to allow convenient and unobstructed access for inspection, cleaning, and routine maintenance of the following:

- a. Outdoor air intake areaways or plenums
- b. Mixed-air plenums
- c. Upstream surface of each heating, cooling, and heat-recovery coil or coil assembly having a total of four rows or fewer
- d. Both upstream and downstream surface of each heating, cooling, and heat-recovery coil having a total of more than four rows and air washers, evaporative coolers, heat wheels, and other heat exchangers
- e. Air cleaners
- f. Drain pans and drain seals
- g. Fans
- h. Humidifiers

**5.14 Building Envelope and Interior Surfaces.** The building envelope and interior surfaces within the building envelope shall be designed in accordance with the following subsections.

**5.14.1 Building Envelope.** The building envelope, including roofs, walls, fenestration systems, and foundations, shall comply with the following:

- a. A weather barrier or other means shall be provided to prevent liquid-water penetration into the envelope.

**Exception to 5.14.1(a):** When the envelope is engineered to allow incidental water penetration to occur without resulting in damage to the envelope construction.

- b. An appropriately placed vapor retarder or other means shall be provided to limit water vapor diffusion to prevent condensation on cold surfaces within the envelope.

**Exception to 5.14.1(b):** When the envelope is engineered to manage incidental condensation without resulting in damage to the envelope construction.

- c. Exterior joints, seams, or penetrations in the building envelope that are pathways for air leakage shall be caulked, gasketed, weather-stripped, provided with a continuous air barrier, or otherwise sealed to limit infiltration through the envelope to reduce uncontrolled entry of outdoor air moisture and pollutants.

**Informative Note:** In localities where soils contain high concentrations of radon or other soil gas contaminants, the authority having jurisdiction might impose additional measures, such as subslab depressurization.

**5.14.2 Condensation on Interior Surfaces.** Pipes, ducts, and other surfaces within the building whose surface temperatures are expected to fall below the surrounding dew-point temperature shall be insulated. The insulation system thermal resistance and material characteristics shall prevent condensate from forming on the exposed surface and within the insulating material.

**Exceptions:**

1. Where condensate will wet only surfaces that will be managed to prevent or control mold growth.
2. Where local practice has demonstrated that condensation does not result in mold growth.

**5.15 Buildings with Attached Parking Garages.** In order to limit the entry of vehicular exhaust into occupiable spaces, buildings with attached parking garages shall be designed to

- a. maintain the garage pressure at or below the pressure of the adjacent occupiable spaces,
- b. use a vestibule to provide an airlock between the garage and the adjacent occupiable spaces, or
- c. otherwise limit migration of air from the attached parking garage into the adjacent occupiable spaces of the building in a manner acceptable to the authority having jurisdiction.

**5.16 Air Classification and Recirculation.** Air shall be classified, and its recirculation shall be limited in accordance with the following subsections.

**5.16.1 Classification.** Air (return, transfer, or exhaust air) leaving each space or location shall be designated at an expected air-quality classification not less than that shown in Tables 5.16.1, 6.2.2.1, or 6.5, or as approved by the authority having jurisdiction. Air leaving spaces or locations that are not listed in Table 5.16.1, 6.2.2.1, or 6.5 shall be designated with the same classification as air from the most similar space

**TABLE 5.16.1 Airstreams or Sources**

Description	Air Class
Diazo printing equipment discharge	4
Commercial kitchen grease hoods	4
Commercial kitchen hoods other than grease	3
Laboratory hoods	4 <sup>a</sup>
Residential kitchen hoods	3
Hydraulic elevator machine room	2

a. Air Class 4 unless determined otherwise by the Environmental Health and Safety professional responsible to the owner or to the owner's designee

or location listed in terms of occupant activities and building construction.

**Exception:** Air from spaces where ETS is present. (Classification of air from spaces where ETS is present is not addressed. Spaces that are expected to include ETS do not have a classification listed in Table 6.2.2.1.)

**Informative Note:** Classifications in Tables 5.16.1, 6.2.2.1, and 6.5 are based on relative contaminant concentration using the following subjective criteria:

- Class 1: Air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odor
- Class 2: Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odors (Class 2 air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.)
- Class 3: Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor
- Class 4: Air with highly objectionable fumes or gases or with potentially dangerous particles, bioaerosols, or gases, at concentrations high enough to be considered as harmful

**5.16.2 Redesignation**

**5.16.2.1 Air Cleaning.** If air leaving a space or location passes through an air-cleaning system, redesignation of the cleaned air to a cleaner classification shall be permitted where based on the subjective criteria in the informative note for Section 5.16.1 and where approved by the authority having jurisdiction.

**5.16.2.2 Transfer.** A mixture of air that has been transferred through or returned from spaces or locations with different air classes shall be redesignated with the highest classification among the air classes mixed.

**Informative Note:** For example, mixed return air to a common system serving both a Class 1 space and a Class 2 space is designated as Class 2 air.

**5.16.2.3 Ancillary Spaces.** Redesignation of Class 1 air to Class 2 air shall be permitted for Class 1 spaces that are ancillary to Class 2 spaces.

**Informative Note:** For example, an office within a restaurant might be designated as a space ancillary to a Class 2 space, thus enabling the office to receive Class 2 air.

**5.16.3 Recirculation Limitations.** When the Ventilation Rate Procedure of Section 6 is used to determine ventilation airflow values, recirculation of air shall be limited in accordance with the requirements of this section.

**5.16.3.1 Class 1 Air.** Recirculation or transfer of Class 1 air to any space shall be permitted.

**5.16.3.2 Class 2 Air**

**5.16.3.2.1** Recirculation of Class 2 air within the space of origin shall be permitted.

**5.16.3.2.2** Recirculation or transfer of Class 2 air to other Class 2 or Class 3 spaces shall be permitted, provided that the other spaces are used for the same or similar purpose or task and involve the same or similar pollutant sources as the Class 2 space.

**5.16.3.2.3** Transfer of Class 2 air to toilet rooms shall be permitted.

**5.16.3.2.4** Recirculation or transfer of Class 2 air to Class 4 spaces shall be permitted.

**5.16.3.2.5** Class 2 air shall not be recirculated or transferred to Class 1 spaces.

**Exception:** When using any energy recovery device, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. Recirculated Class 2 air shall not exceed 10% of the outdoor air intake flow.

**5.16.3.3 Class 3 Air**

**5.16.3.3.1** Recirculation of Class 3 air within the space of origin shall be permitted.

**5.16.3.3.2** Class 3 air shall not be recirculated or transferred to any other space.

**Exception:** When using any energy recovery device, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. Recirculated Class 3 air shall not exceed 5% of the outdoor air intake flow.

**5.16.3.4 Class 4 Air.** Class 4 air shall not be recirculated or transferred to any space or recirculated within the space of origin.

**5.16.4 Documentation.** Design documentation shall indicate the justification for classification of air from any occupancy category, airstream, or location not listed in Table 5.16.1, 6.2.2.1, or 6.5.

**5.17 Requirements for Buildings Containing ETS Areas and ETS-Free Areas.** The requirements of this section must be met when a building contains both ETS areas and ETS-free areas. Such buildings shall be constructed and operated in accordance with Sections 5.17.1 through 5.17.8. This section does not purport to achieve acceptable indoor air quality in ETS areas.

**5.17.1 Classification.** All spaces shall be classified as either ETS-free areas or ETS areas.

**5.17.2 Pressurization.** ETS-free areas shall be at a positive pressure with respect to any adjacent or connected ETS areas.

**Exceptions:**

1. Dwelling units, including hotel and motel guestrooms, and adjacent properties under different ownership with separation walls that are structurally independent and that contain no openings. This exception shall apply only when
  - a. the separation walls are constructed as smoke barriers in accordance with the requirements of applicable standards;
  - b. the separation walls include an air barrier consisting of a continuous membrane or surface treatment in the separation wall that has documented resistance to air leakage—continuity of the barrier shall be maintained at openings for pipes, ducts, and other conduits and at points where the barrier meets the outside walls and other barriers; and
  - c. interior corridors common to ETS and ETS-free areas are mechanically supplied with outdoor air at the rate of 0.1 cfm/ft<sup>2</sup> (0.5 L/s·m<sup>2</sup>).
2. Adjacent spaces otherwise required to be held at negative pressure and posted with signs due to the presence of hazardous or flammable materials or vapors.

**Informative Note:** Examples of methods for demonstrating relative pressure include engineering analysis, pressure differential measurement, and airflow measurement.

**5.17.3 Separation.** Solid walls, floors, ceilings, and doors equipped with automatic closing mechanisms shall separate ETS areas from ETS-free areas.

**Exception:** Openings without doors are permitted in the separation where engineered systems are designed to provide airflow from ETS-free areas into ETS areas, notwithstanding eddies that may occur in the immediate vicinity of the boundary between the ETS and ETS-free areas and reverse flow that may occur due to short-term conditions such as wind gusts.

**Informative Note:** Examples of methods for demonstrating air motion are engineering analysis and the use of a directional airflow indicator at representative locations in the opening, such as on 1 ft (0.3 m) centers or at locations required for duct traverses in standard testing and balancing procedures, such as those described in ASHRAE Standard 111<sup>15</sup>.

**5.17.4 Transfer Air.** When air is transferred from ETS-free areas to ETS areas, the transfer airflow rate shall be maintained regardless of whether operable doors or windows between ETS-free and ETS areas are opened or closed. Acceptable means of doing so include fixed openings in doors, walls, or floors, transfer grilles, transfer ducts, or unducted air plenums with air pressure differentials in compliance with Section 5.17.2.

**5.17.5 Recirculation.** Air-handling and natural ventilation systems shall not recirculate or transfer air from an ETS area to an ETS-free area.

**5.17.6 Exhaust Systems.** Exhaust or relief air from an ETS area shall be discharged such that none of the air is recirculated back into any ETS-free area.

**5.17.7 Signage.** A sign shall be posted outside each entrance to each ETS area. The sign shall state, as a minimum, “This Area May Contain Environmental Tobacco Smoke” in letters at least 1 in. (25 mm) high or otherwise in compliance with accessibility guidelines.

**Exception:** Instead of the specified sign, equivalent notification means acceptable to the authority having jurisdiction may be used.

**Informative Note:** Based on the definition of *ETS area*, such a sign might be posted outside a larger ETS area that includes the area where smoking is permitted.

**5.17.8 Reclassification.** An area that was previously an ETS area but now meets the requirements of an ETS-free area shall be permitted to be classified as such where smoke exposure has stopped and odor and irritation from residual ETS contaminants are not apparent.

## 6. PROCEDURES

**6.1 General.** The Ventilation Rate Procedure, the IAQ Procedure, the Natural Ventilation Procedure, or a combination thereof shall be used to meet the requirements of this section. In addition, the requirements for exhaust ventilation in Section 6.5 shall be met regardless of the method used to determine minimum outdoor airflow rates.

**Informative Note:** Although the intake airflow determined using each of these approaches may differ significantly because of assumptions about the design, any of these approaches is a valid basis for design.

**6.1.1 Ventilation Rate Procedure.** The prescriptive design procedure presented in Section 6.2, in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area, shall be permitted to be used for any zone or system.

**Informative Note:** The Ventilation Rate Procedure minimum rates are based on contaminant sources and source strengths that are typical for the listed occupancy categories.

**6.1.2 IAQ Procedure.** This performance-based design procedure presented in Section 6.3, in which the building outdoor air intake rates and other system design parameters are based on an analysis of contaminant sources, contaminant concentration limits, and level of perceived indoor air acceptability, shall be permitted to be used for any zone or system.

**6.1.3 Natural Ventilation Procedure.** The prescriptive design procedure presented in Section 6.4, in which outdoor air is provided through openings to the outdoors, shall be permitted to be used for any zone or portion of a zone in conjunction with mechanical ventilation systems in accordance with Section 6.4.

**6.2 Ventilation Rate Procedure.** The outdoor air intake flow ( $V_{ot}$ ) for a ventilation system shall be determined in accordance with Sections 6.2.1 through 6.2.7.

**Informative Note:** Additional explanation of terms used below is contained in Normative Appendix A, along with a ventilation system schematic (Figure A-1).

**6.2.1 Outdoor Air Treatment.** Each ventilation system that provides outdoor air through a supply fan shall comply with the following subsections.

**Exception:** Systems supplying air for enclosed parking garages, warehouses, storage rooms, janitor’s closets, trash rooms, recycling areas, shipping/receiving/distribution areas.

**Informative Note:** Occupied spaces ventilated with outdoor air that is judged to be unacceptable are subject to reduced air quality when outdoor air is not cleaned prior to introduction to the occupied spaces.

**6.2.1.1 Particulate Matter Smaller than 10 Micrometers (PM<sub>10</sub>).** In buildings located in an area where the national standard or guideline for PM<sub>10</sub><sup>1</sup> is exceeded, particle filters or air-cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces. Particulate matter filters or air cleaners shall have an efficiency reporting value (MERV) of not less than 6 where rated in accordance with ASHRAE Standard 52.2<sup>12</sup>.

**Informative Note:** See Informative Appendix F for resources regarding selected PM<sub>10</sub> national standards and guidelines.

**6.2.1.2 Particulate Matter Smaller than 2.5 Micrometers (PM<sub>2.5</sub>).** In buildings located in an area where the national standard or guideline for PM<sub>2.5</sub><sup>1</sup> is exceeded, particle filters or air-cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces. Particulate matter filters or air cleaners shall have an efficiency reporting value (MERV) of not less than 11 where rated in accordance with ASHRAE Standard 52.2<sup>12</sup>.

**Informative Note:** See Informative Appendix F for resources regarding selected PM<sub>2.5</sub> national standards and guidelines.

**6.2.1.3 Ozone.** Air-cleaning devices for ozone shall be provided when the most recent three-year average annual fourth-highest daily maximum eight-hour average ozone concentration exceeds 0.107 ppm (209 µg/m<sup>3</sup>).

Such air-cleaning devices shall have a volumetric ozone removal efficiency of not less than 40% where installed, operated, and maintained in accordance with manufacturer recommendations and shall be approved by the authority having jurisdiction. Such devices shall be operated where the outdoor ozone levels are expected to exceed 0.107 ppm (209 µg/m<sup>3</sup>).

**Exceptions:** Air cleaning for ozone shall not be required where

1. the system design outdoor air intake flow is 1.5 ach or less,
2. controls are provided that sense outdoor ozone level and reduce intake airflow to 1.5 ach or less while complying with the outdoor airflow requirements of Section 6, or
3. outdoor air is brought into the building and heated by direct-fired makeup air units.

**Informative Note:** See Informative Appendix F for a map of United States locations exceeding the most recent three-year average annual fourth-highest daily maximum eight-hour average ozone concentration of 0.107 ppm (209 µg/m<sup>3</sup>).

**6.2.1.4 Other Outdoor Contaminants.** In buildings located in an area where the national standard for one or more contaminants not addressed in Section 6.2.1 is exceeded, any

design assumptions and calculations related to the impact on indoor air quality shall be included in the design documents.

**6.2.2 Zone Calculations.** Ventilation zone parameters shall be determined in accordance with Sections 6.2.2.1 through 6.2.2.3 for ventilation zones served by the ventilation system.

**6.2.2.1 Breathing Zone Outdoor Airflow.** The outdoor airflow required in the breathing zone ( $V_{bz}$ ) of the occupiable space or spaces in a ventilation zone shall be not less than the value determined in accordance with Equation 6.2.2.1.

$$V_{bz} = R_p \times P_z + R_a \times A_z \quad (6.2.2.1)$$

where

- $A_z$  = zone floor area, the net occupiable floor area of the ventilation zone, ft<sup>2</sup> (m<sup>2</sup>)
- $P_z$  = zone population, the number of people in the ventilation zone during use
- $R_p$  = outdoor airflow rate required per person as determined from Table 6.2.2.1

**Informative Note:** These values are based on adapted occupants.

- $R_a$  = outdoor airflow rate required per unit area as determined from Table 6.2.2.1

**Informative Note:** Equation 6.2.2.1 accounts for people-related sources and area-related sources independently in the determination of the outdoor air rate required at the breathing zone. The use of Equation 6.2.2.1 in the context of this standard does not necessarily imply that simple addition of outdoor airflow rates for different sources can be applied to any other aspect of indoor air quality.

**6.2.2.1.1 Design Zone Population.** Design zone population ( $P_z$ ) shall equal the largest (peak) number of people expected to occupy the ventilation zone during typical use.

**Exceptions:**

1. Where the number of people expected to occupy the ventilation zone fluctuates, zone population equal to the average number of people shall be permitted, provided such average is determined in accordance with Section 6.2.6.2.
2. Where the largest or average number of people expected to occupy the ventilation zone cannot be established for a specific design, an estimated value for zone population shall be permitted, provided such value is the product of the net occupiable area of the ventilation zone and the default occupant density listed in Table 6.2.2.1.

**6.2.2.2 Zone Air Distribution Effectiveness.** The zone air distribution effectiveness ( $E_z$ ) shall be not greater than the default value determined using Table 6.2.2.2.

**Informative Note:** For some configurations, the default value depends upon space and supply air temperature.

**6.2.2.3 Zone Outdoor Airflow.** The zone outdoor airflow ( $V_{oz}$ ) provided to the ventilation zone by the supply air distribution system shall be determined in accordance with Equation 6.2.2.3.

$$V_{oz} = V_{bz}/E_z \quad (6.2.2.3)$$

**6.2.3 Single-Zone Systems.** For ventilation systems wherein one or more air handlers supply a mixture of outdoor air and recirculated air to only one ventilation zone, the outdoor air intake flow ( $V_{ot}$ ) shall be determined in accordance with Equation 6.2.3.

$$V_{ot} = V_{oz} \quad (6.2.3)$$

**6.2.4 100% Outdoor Air Systems.** For ventilation systems wherein one or more air handlers supply only outdoor air to one or more ventilation zones, the outdoor air intake flow ( $V_{ot}$ ) shall be determined in accordance with Equation 6.2.4.

$$V_{ot} = \Sigma_{all\ zones} V_{oz} \quad (6.2.4)$$

**6.2.5 Multiple-Zone Recirculating Systems.** For ventilation systems wherein one or more air handlers supply a mixture of outdoor air and recirculated air to more than one ventilation zone, the outdoor air intake flow ( $V_{ot}$ ) shall be determined in accordance with Sections 6.2.5.1 through 6.2.5.4.

**6.2.5.1 Primary Outdoor Air Fraction.** Primary outdoor air fraction ( $Z_{pz}$ ) shall be determined for ventilation zones in accordance with Equation 6.2.5.1.

$$Z_{pz} = V_{oz}/V_{pz} \quad (6.2.5.1)$$

where  $V_{pz}$  is the zone primary airflow to the ventilation zone, including outdoor air and recirculated air.

- a. For VAV-system design purposes,  $V_{pz}$  is the lowest zone primary airflow value expected at the design condition analyzed.
- b. In some cases, it is permitted to determine these parameters for only selected zones as outlined in Normative Appendix A.

**6.2.5.2 System Ventilation Efficiency.** The system ventilation efficiency ( $E_v$ ) shall be determined in accordance with Table 6.2.5.2 or Normative Appendix A.

**6.2.5.3 Uncorrected Outdoor Air Intake.** The uncorrected outdoor air intake ( $V_{ou}$ ) flow shall be determined in accordance with Equation 6.2.5.3.

$$V_{ou} = D \Sigma_{all\ zones} (R_p \times P_z) + \Sigma_{all\ zones} (R_a \times A_z) \quad (6.2.5.3)$$

**6.2.5.3.1 Occupant Diversity.** The occupant diversity ratio ( $D$ ) shall be determined in accordance with Equation 6.2.5.3.1 to account for variations in population within the ventilation zones served by the system.

$$D = P_s / \Sigma_{all\ zones} P_z \quad (6.2.5.3.1)$$

where the system population ( $P_s$ ) is the total population in the area served by the system.

**Exception:** Alternative methods to account for occupant diversity shall be permitted, provided the resulting  $V_{ou}$  value is not less than that determined using Equation 6.2.5.3.

**Informative Note:** The uncorrected outdoor air intake ( $V_{ou}$ ) is adjusted for occupant diversity, but it is not corrected for system ventilation efficiency.

**TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone**  
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate $R_p$		Area Outdoor Air Rate $R_a$		Notes	Default Values			
	cfm/ person	L/s· person	cfm/ft <sup>2</sup>	L/s·m <sup>2</sup>		Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		Air Class
						#/1000 ft <sup>2</sup> or #/100 m <sup>2</sup>	cfm/ person	L/s· person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3	H	35	12	5.9	1
Multiuse assembly	7.5	3.8	0.06	0.3	H	100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
Kitchen (cooking)	7.5	3.8	0.12	0.6		20	14	7.0	2

**GENERAL NOTES FOR TABLE 6.2.2.1**

- Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
- Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.
- Air density:** Volumetric airflow rates are based on dry air density of 0.075 lb<sub>da</sub>/ft<sup>3</sup> (1.2 kg<sub>da</sub>/m<sup>3</sup>) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.
- Default occupant density:** The default occupant density shall be used where the actual occupant density is not known.
- Default combined outdoor air rate (per person):** Rate is based on the default occupant density.
- Unlisted occupancies:** 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, activities, and building construction shall be used.

**ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1**

- For high-school and college libraries, the values shown for “Public Assembly Spaces—Libraries” shall be used.
- Rate may not be sufficient where stored materials include those having potentially harmful emissions.
- Rate does not allow for humidity control. “Deck area” refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
- Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.
- Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.
- Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
- Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.
- Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

**TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone (Continued)**

(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate $R_p$		Area Outdoor Air Rate $R_a$		Notes	Default Values			
	cfm/ person	L/s· person	cfm/ft <sup>2</sup>	L/s·m <sup>2</sup>		Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		Air Class
						#/1000 ft <sup>2</sup> or #/100 m <sup>2</sup>	cfm/ person	L/s· person	
General									
Break rooms	5	2.5	0.06	0.3	H	25	7	3.5	1
Coffee stations	5	2.5	0.06	0.3	H	20	8	4	1
Conference/meeting	5	2.5	0.06	0.3	H	50	6	3.1	1
Corridors	—	—	0.06	0.3	H	—			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3	H	10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3	H	20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3	H	30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3	H	120	6	2.8	1
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3	H	10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office space	5	2.5	0.06	0.3	H	5	17	8.5	1
Reception areas	5	2.5	0.06	0.3	H	30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3	H	60	6	3.0	1

**GENERAL NOTES FOR TABLE 6.2.2.1**

- Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
- Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.
- Air density:** Volumetric airflow rates are based on dry air density of 0.075 lb<sub>da</sub>/ft<sup>3</sup> (1.2 kg<sub>da</sub>/m<sup>3</sup>) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.
- Default occupant density:** The default occupant density shall be used where the actual occupant density is not known.
- Default combined outdoor air rate (per person):** Rate is based on the default occupant density.
- Unlisted occupancies:** 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, activities, and building construction shall be used.

**ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1**

- For high-school and college libraries, the values shown for “Public Assembly Spaces—Libraries” shall be used.
- Rate may not be sufficient where stored materials include those having potentially harmful emissions.
- Rate does not allow for humidity control. “Deck area” refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
- Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.
- Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.
- Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
- Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.
- Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.



**TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone (Continued)**

(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate $R_p$		Area Outdoor Air Rate $R_a$		Notes	Default Values			
	cfm/ person	L/s· person	cfm/ft <sup>2</sup>	L/s·m <sup>2</sup>		Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		Air Class
						#/1000 ft <sup>2</sup> or #/100 m <sup>2</sup>	cfm/ person	L/s· person	
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3	H	5	17	8.5	2
Banks or bank lobbies	7.5	3.8	0.06	0.3	H	15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3	H	4	20	10.0	1
Freezer and refrigerated spaces (<50°F)	10	5	0	0	E	0	0	0	2
General manufacturing (excludes heavy industrial and processes using chemicals)	10	5.0	0.18	0.9		7	36	18	3
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	10	5	0.12	0.6	B	2	70	35	2
Sorting, packing, light assembly	7.5	3.8	0.12	0.6		7	25	12.5	2
Telephone closets	—	—	0.00	0.0		—			1
Transportation waiting	7.5	3.8	0.06	0.3	H	100	8	4.1	1
Warehouses	10	5	0.06	0.3	B	—			2
Public Assembly Spaces									
Auditorium seating area	5	2.5	0.06	0.3	H	150	5	2.7	1
Places of religious worship	5	2.5	0.06	0.3	H	120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3	H	70	6	2.9	1
Legislative chambers	5	2.5	0.06	0.3	H	50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3	H	150	5	2.7	1
Museums (children’s)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums/galleries	7.5	3.8	0.06	0.3	H	40	9	4.6	1

**GENERAL NOTES FOR TABLE 6.2.2.1**

- 1 Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
- 2 Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.
- 3 Air density:** Volumetric airflow rates are based on dry air density of 0.075 lb<sub>da</sub>/ft<sup>3</sup> (1.2 kg<sub>da</sub>/m<sup>3</sup>) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.
- 4 Default occupant density:** The default occupant density shall be used where the actual occupant density is not known.
- 5 Default combined outdoor air rate (per person):** Rate is based on the default occupant density.
- 6 Unlisted occupancies:** 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, activities, and building construction shall be used.

**ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1**

- For high-school and college libraries, the values shown for "Public Assembly Spaces—Libraries" shall be used.
- Rate may not be sufficient where stored materials include those having potentially harmful emissions.
- Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
- Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.
- Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.
- Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
- Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.
- Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

**TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone (Continued)**

(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate <i>R<sub>p</sub></i>		Area Outdoor Air Rate <i>R<sub>a</sub></i>		Notes	Default Values			
	cfm/ person	L/s· person	cfm/ft <sup>2</sup>	L/s·m <sup>2</sup>		Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		Air Class
						#/1000 ft <sup>2</sup> or #/100 m <sup>2</sup>	cfm/ person	L/s· person	
Residential									
Dwelling unit	5	2.5	0.06	0.3	F, G, H	F			1
Common corridors	—	—	0.06	0.3	H				1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3	H	40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3	H	25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3	H	8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.12	0.6		20	14	7.0	2
Sports and Entertainment									
Gym, sports arena (play area)	20	10	0.18	0.9	E	7	45	23	2
Spectator areas	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Swimming (pool & deck)	—	—	0.48	2.4	C	—			2
Disco/dance floors	20	10	0.06	0.3	H	100	21	10.3	2
Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, studios	10	5	0.06	0.3	D, H	70	11	5.4	1

**GENERAL NOTES FOR TABLE 6.2.2.1**

- 1 Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
- 2 Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.
- 3 Air density:** Volumetric airflow rates are based on dry air density of 0.075 lb<sub>da</sub>/ft<sup>3</sup> (1.2 kg<sub>da</sub>/m<sup>3</sup>) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.
- 4 Default occupant density:** The default occupant density shall be used where the actual occupant density is not known.
- 5 Default combined outdoor air rate (per person):** Rate is based on the default occupant density.
- 6 Unlisted occupancies:** 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, activities, and building construction shall be used.

**ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1**

- For high-school and college libraries, the values shown for “Public Assembly Spaces—Libraries” shall be used.
- Rate may not be sufficient where stored materials include those having potentially harmful emissions.
- Rate does not allow for humidity control. “Deck area” refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
- Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.
- Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.
- Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
- Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.
- Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

**TABLE 6.2.2.2 Zone Air Distribution Effectiveness**

Air Distribution Configuration	$E_z$
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level (See Note 6)	1.0
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust, return, or both.	0.8
Makeup supply drawn in near to the exhaust, return, or both locations.	0.5

**NOTES:**

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling supply" includes any point above the breathing zone.
4. "Floor supply" includes any point below the breathing zone.
5. As an alternative to using the above values,  $E_z$  may be regarded as equal to air-change effectiveness determined in accordance with ASHRAE Standard 129<sup>16</sup> for air distribution configurations except unidirectional flow.
6. For lower velocity supply air,  $E_z = 0.8$ .

**6.2.5.3.2 Design System Population.** Design system population ( $P_s$ ) shall equal the largest (peak) number of people expected to occupy all ventilation zones served by the ventilation system during use.

**Informative Note:** Design system population is always equal to or less than the sum of design zone population for all zones in the area served by the system because all zones may not be simultaneously occupied at design population.

**6.2.5.4 Outdoor Air Intake.** The design outdoor air intake flow ( $V_{ot}$ ) shall be determined in accordance with Equation 6.2.5.4.

$$V_{ot} = V_{ou}/E_v \quad (6.2.5.4)$$

## 6.2.6 Design for Varying Operating Conditions

**6.2.6.1 Variable Load Conditions.** Ventilation systems shall be designed to be capable of providing not less than the minimum ventilation rates required in the breathing zone where the zones served by the system are occupied, including all full- and part-load conditions.

**Informative Note:** The minimum outdoor air intake flow may be less than the design value at part-load conditions.

**TABLE 6.2.5.2 System Ventilation Efficiency**

Max ( $Z_{pz}$ )	$E_v$
$\leq 0.15$	1.0
$\leq 0.25$	0.9
$\leq 0.35$	0.8
$\leq 0.45$	0.7
$\leq 0.55$	0.6
$> 0.55$	Use Normative Appendix A

**NOTES:**

1. "Max ( $Z_{pz}$ )" refers to the largest value of  $Z_{pz}$ , calculated using Equation 6.2.5.1, among all the ventilation zones served by the system.
2. For values of Max ( $Z_{pz}$ ) between 0.15 and 0.55, the corresponding value of  $E_v$  may be determined by interpolating the values in the table.
3. The values of  $E_v$  in this table are based on a 0.15 average outdoor air fraction for the system. For systems with higher values of the average outdoor air fraction, this table may result in unrealistically low values of  $E_v$ , and the use of Normative Appendix A may yield more practical results.

**6.2.6.2 Short-Term Conditions.** Where it is known that peak occupancy will be of short duration, ventilation will be varied or interrupted for a short period of time, or both, the design shall be permitted to be based on the average conditions over a time period ( $T$ ) determined by Equation 6.2.6.2-1 or Equation 6.2.6.2-2.

$$T = 3v/V_{bz} \quad (\text{I-P}) \quad (6.2.6.2-1)$$

$$T = 50v/V_{bz} \quad (\text{SI}) \quad (6.2.6.2-2)$$

where

$T$  = averaging time period, min

$v$  = the volume of the ventilation zone where averaging is being applied, ft<sup>3</sup> (m<sup>3</sup>)

$V_{bz}$  = the breathing zone outdoor airflow calculated using Equation 6.2.2.1 and the design value of the zone population ( $P_z$ ), cfm (L/s)

Acceptable design adjustments based on this optional provision include the following:

- a. Zones with fluctuating occupancy: The zone population ( $P_z$ ) shall be permitted to be averaged over time ( $T$ ).
- b. Zones with intermittent interruption of supply air: The average outdoor airflow supplied to the breathing zone over time ( $T$ ) shall be not less than the breathing zone outdoor airflow ( $V_{bz}$ ) calculated using Equation 6.2.2.1.
- c. Systems with intermittent closure of the outdoor air intake: The average outdoor air intake over time ( $T$ ) shall be not less than the minimum outdoor air intake ( $V_{ot}$ ) calculated using Equation 6.2.3, 6.2.4, or 6.2.5.4 as appropriate.

**6.2.7 Dynamic Reset.** The system shall be permitted to be designed to reset the outdoor air intake flow ( $V_{ot}$ ), the space or ventilation zone airflow ( $V_{oz}$ ) as operating conditions change, or both.

**6.2.7.1 Demand Control Ventilation (DCV).** DCV shall be permitted as an optional means of dynamic reset.

**Exception:** CO<sub>2</sub>-based DCV shall not be applied in zones with indoor sources of CO<sub>2</sub> other than occupants or with CO<sub>2</sub> removal mechanisms, such as gaseous air cleaners.

**6.2.7.1.1** For DCV zones in the occupied mode, breathing zone outdoor airflow ( $V_{bz}$ ) shall be reset in response to current population.

**6.2.7.1.2** For DCV zones in the occupied mode, breathing zone outdoor airflow ( $V_{bz}$ ) shall be not less than the building component ( $R_a \times A_z$ ) for the zone.

**Exception:** Breathing zone outdoor airflow shall be permitted to be reduced to zero for zones in occupied standby mode for the occupancy categories indicated in Table 6.2.2.1, provided that airflow is restored to  $V_{bz}$  whenever occupancy is detected.

**6.2.7.1.3 Documentation.** A written description of the equipment, methods, control sequences, setpoints, and the intended operational functions shall be provided. A table shall be provided that shows the minimum and maximum outdoor intake airflow for each system.

**6.2.7.2 Ventilation Efficiency.** Variations in the efficiency with which outdoor air is distributed to the occupants under different ventilation system airflows and temperatures shall be permitted as an optional basis of dynamic reset.

**6.2.7.3 Outdoor Air Fraction.** A higher fraction of outdoor air in the air supply due to intake of additional outdoor air for free cooling or exhaust air makeup shall be permitted as an optional basis of dynamic reset.

**6.3 Indoor Air Quality (IAQ) Procedure.** Breathing zone outdoor airflow ( $V_{bz}$ ) shall be determined in accordance with Sections 6.3.1 through 6.3.5.

**6.3.1 Contaminant Sources.** Each contaminant of concern, for purposes of the design, shall be identified. For each contaminant of concern, indoor sources and outdoor sources shall be identified, and the emission rate for each contaminant of concern from each source shall be determined. Where two or more contaminants of concern target the same organ system, these contaminants shall be considered to be a contaminant mixture.

**Informative Note:** Informative Appendix C provides information for some potential contaminants of concern, including the organs they affect.

**6.3.2 Contaminant Concentration.** For each contaminant of concern, a concentration limit and its corresponding exposure period and an appropriate reference to a cognizant authority shall be specified. For each contaminant mixture of concern, the ratio of the concentration of each contaminant to its concentration limit shall be determined, and the sum of these ratios shall be not greater than one.

**Exception:** Consideration of odors in determining concentration limits shall not be required.

**Informative Notes:**

1. Odors are addressed in Section 6.3.4.2.
2. Informative Appendix C includes concentration guidelines for some potential contaminants of concern.

**6.3.3 Perceived Indoor Air Quality.** The design level of indoor air acceptability shall be specified in terms of the percentage of building occupants, visitors, or both expressing satisfaction with perceived IAQ.

**6.3.4 Design Approach.** Zone and system outdoor airflow rates shall be the larger of those determined in accordance with Section 6.3.4.1 and either Section 6.3.4.2 or 6.3.4.3, based on emission rates, concentration limits, and other relevant design parameters.

**6.3.4.1 Mass Balance Analysis.** Using a steady-state or dynamic mass-balance analysis, the minimum outdoor airflow rates required to achieve the concentration limits specified in Section 6.3.2 shall be determined for each contaminant or contaminant mixture of concern within each zone served by the system.

**Informative Notes:**

1. Informative Appendix E includes steady-state mass-balance equations that describe the impact of air cleaning on outdoor air and recirculation rates for ventilation systems serving a single zone.
2. In the completed building, measurement of the concentration of contaminants or contaminant mixtures of concern may be useful as a means of checking the accuracy of the design mass-balance analysis, but such measurement is not required for compliance.

**6.3.4.2 Subjective Evaluation.** Using a subjective occupant evaluation conducted in the completed building, the minimum outdoor airflow rates required to achieve the level of acceptability specified in Section 6.3.3 shall be determined within each zone served by the system.

**Informative Notes:**

1. Informative Appendix C presents one approach to subjective occupant evaluation.
2. Level of acceptability often increases in response to increased outdoor airflow rates, increased level of indoor or outdoor air cleaning, or decreased indoor or outdoor contaminant emission rate.

**6.3.4.3 Similar Zone.** The minimum outdoor airflow rates shall be not less than those found in accordance with Section 6.3.4.2 for a substantially similar zone.

**6.3.5 Combined IAQ Procedure and Ventilation Rate Procedure.** The IAQ Procedure in conjunction with the Ventilation Rate Procedure shall be permitted to be applied to a zone or system. In this case, the Ventilation Rate Procedure shall be used to determine the required zone minimum outdoor airflow, and the IAQ Procedure shall be used to determine the additional outdoor air or air cleaning necessary to achieve the concentration limits of the contaminants and contaminant mixtures of concern.

**Informative Note:** The improvement of indoor air quality through the use of air cleaning or provision of additional outdoor air in conjunction with minimum ventilation rates may be quantified using the IAQ Procedure.

**6.3.6 Documentation.** Where the IAQ Procedure is used, the following information shall be included in the design documentation: the contaminants and contaminant mixtures of concern considered in the design process, the sources and emission rates of the contaminants of concern, the concentration limits and exposure periods and the references for these limits, and the analytical approach used to determine ventila-

tion rates and air-cleaning requirements. The contaminant monitoring and occupant or visitor evaluation plans shall also be included in the documentation.

**6.4 Natural Ventilation Procedure.** Natural ventilation systems shall be designed in accordance with this section and shall include mechanical ventilation systems designed in accordance with Section 6.2, Section 6.3, or both.

**Exceptions:**

1. An engineered natural ventilation system, where approved by the authority having jurisdiction, need not meet the requirements of Section 6.4.
2. The mechanical ventilation systems shall not be required where
  - a. natural ventilation openings that comply with the requirements of Section 6.4 are permanently open or have controls that prevent the openings from being closed during periods of expected occupancy or
  - b. the zone is not served by heating or cooling equipment.

**6.4.1 Floor Area to Be Ventilated.** Spaces, or portions of spaces, to be naturally ventilated shall be located within a distance based on the ceiling height, as determined by Sections 6.4.1.1, 6.4.1.2, or 6.4.1.3, from operable wall openings that meet the requirements of Section 6.4.2. For spaces with ceilings that are not parallel to the floor, the ceiling height shall be determined in accordance with Section 6.4.1.4.

**6.4.1.1 Single Side Opening.** For spaces with operable openings on one side of the space, the maximum distance from the operable openings shall be not more than  $2H$ , where  $H$  is the ceiling height.

**6.4.1.2 Double Side Opening.** For spaces with operable openings on two opposite sides of the space, the maximum distance from the operable openings shall be not more than  $5H$ , where  $H$  is the ceiling height.

**6.4.1.3 Corner Openings.** For spaces with operable openings on two adjacent sides of a space, the maximum distance from the operable openings shall be not more than  $5H$  along a line drawn between the two openings that are farthest apart. Floor area outside that line shall comply with Section 6.4.1.1.

**6.4.1.4 Ceiling Height.** The ceiling height ( $H$ ) to be used in Sections 6.4.1.1 through 6.4.1.3 shall be the minimum ceiling height in the space.

**Exception:** For ceilings that are increasing in height as distance from the openings is increased, the ceiling height shall be determined as the average height of the ceiling within 6 m (20 ft) from the operable openings.

**6.4.2 Location and Size of Openings.** Spaces or portions of spaces to be naturally ventilated shall be permanently open to operable wall openings directly to the outdoors. The openable area shall be not less than 4% of the net occupiable floor area. Where openings are covered with louvers or otherwise obstructed, openable area shall be based on the net free unobstructed area through the opening. Where interior rooms, or portions of rooms, without direct openings to the outdoors are

ventilated through adjoining rooms, the opening between rooms shall be permanently unobstructed and have a free area of not less than 8% of the area of the interior room or less than 25 ft<sup>2</sup> (2.3 m<sup>2</sup>).

**6.4.3 Control and Accessibility.** The means to open required operable openings shall be readily accessible to building occupants whenever the space is occupied. Controls shall be designed to coordinate operation of the natural and mechanical ventilation systems.

**6.5 Exhaust Ventilation.** The Prescriptive Compliance Path or the Performance Compliance Path shall be used to meet the requirements of this section. Exhaust makeup air shall be permitted to be any combination of outdoor air, recirculated air, or transfer air.

**6.5.1 Prescriptive Compliance Path.** The design exhaust airflow shall be determined in accordance with the requirements in Table 6.5.

**6.5.2 Performance Compliance Path.** The exhaust airflow shall be determined in accordance with the following subsections.

**6.5.2.1 Contaminant Sources.** Contaminants or mixtures of concern for purposes of the design shall be identified. For each contaminant or mixture of concern, indoor sources (occupants, materials, activities, and processes) and outdoor sources shall be identified, and the emission rate for each contaminant of concern from each source shall be determined.

**Informative Note:** Informative Appendix C provides information for some potential contaminants of concern.

**6.5.2.2 Contaminant Concentration.** For each contaminant of concern, a concentration limit and its corresponding exposure period and an appropriate reference to a cognizant authority shall be specified.

**Informative Note:** Informative Appendix C includes concentration guidelines for some potential contaminants of concern.

**6.5.2.3 Monitoring and control systems** shall be provided to automatically detect contaminant levels of concern and modulate exhaust airflow such that contaminant levels are maintained at not greater than the specified contaminant concentration limits.

**6.6 Design Documentation Procedures.** Design criteria and assumptions shall be documented and made available for operation of the system after installation. See Sections 4.3, 5.1.3, 5.16.4, 6.2.7.1.4, and 6.3.6 regarding assumptions to be detailed in the documentation.

## 7. CONSTRUCTION AND SYSTEM START-UP

### 7.1 Construction Phase

**7.1.1 Application.** The requirements of this section apply to ventilation systems and the spaces they serve in new buildings and additions to or alterations in existing buildings.

**7.1.2 Filters.** Systems designed with particle filters shall not be operated without filters in place.

**7.1.3 Protection of Materials.** When recommended by the manufacturer, building materials shall be protected from rain and other sources of moisture by appropriate in-transit and on-site procedures. Porous materials with visible microbial

**TABLE 6.5 Minimum Exhaust Rates**

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft <sup>2</sup>	Notes	Exhaust Rate, L/s-unit	Exhaust Rate, L/s·m <sup>2</sup>	Air Class
Arenas	—	0.50	B	—	—	1
Art classrooms	—	0.70		—	3.5	2
Auto repair rooms	—	1.50	A	—	7.5	2
Barber shops	—	0.50		—	2.5	2
Beauty and nail salons	—	0.60		—	3.0	2
Cells with toilet	—	1.00		—	5.0	2
Copy, printing rooms	—	0.50		—	2.5	2
Darkrooms	—	1.00		—	5.0	2
Educational science laboratories	—	1.00		—	5.0	2
Janitor closets, trash rooms, recycling	—	1.00		—	5.0	3
Kitchenettes	—	0.30		—	1.5	2
Kitchens—commercial	—	0.70		—	3.5	2
Locker rooms for athletic, industrial, and health care facilities	—	0.50		—	2.5	2
All other locker rooms	—	0.25		—	1.25	2
Shower rooms	20/50		G,I	10/25		2
Paint spray booths	—	—	F	—	—	4
Parking garages	—	0.75	C	—	3.7	2
Pet shops (animal areas)	—	0.90		—	4.5	2
Refrigerating machinery rooms	—	—	F	—	—	3
Residential kitchens	50/100	—	G	25/50	—	2
Soiled laundry storage rooms	—	1.00	F	—	5.0	3
Storage rooms, chemical	—	1.50	F	—	7.5	4
Toilets—private	25/50	—	E, H	12.5/25	—	2
Toilets—public	50/70	—	D, H	25/35	—	2
Woodwork shop/classrooms	—	0.50		—	2.5	2

**NOTES:**

- A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
- B Where combustion equipment is intended to be used on the playing surface additional dilution ventilation, source control, or both shall be provided.
- C Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.
- D Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.
- E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
- F See other applicable standards for exhaust rate.
- G For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
- H Exhaust air that has been cleaned to meet Class 1 criteria from Section 5.16.1 shall be permitted to be recirculated.
- I Rate is per showerhead.

growth shall not be installed. Nonporous materials with visible microbial growth shall be decontaminated.

#### 7.1.4 Protection of Occupied Areas

**7.1.4.1 Application.** The requirements of Section 7.1.4 apply when construction requires a building permit and entails sanding, cutting, grinding, or other activities that generate significant amounts of airborne particles or procedures that generate significant amounts of gaseous contaminants.

**7.1.4.2 Protective Measures.** Measures shall be employed to reduce the migration of construction-generated contaminants to occupied areas.

**Informative Note:** Examples of acceptable measures include, but are not limited to, sealing the construction area

using temporary walls or plastic sheathing, exhausting the construction area, or pressurizing contiguous occupied areas.

**7.1.5 Air Duct System Construction.** Air duct systems shall be constructed in accordance with the following standards, as applicable:

- The following sections of SMACNA's *HVAC Duct Construction Standards—Metal and Flexible*<sup>17</sup>:
  - Section S1.9 of Section 1.3.1, "Duct Construction and Installation Standards"
  - Section 7.4, "Installation Standards for Rectangular Ducts Using Flexible Liner"
  - Section 3.5, "Duct Installation Standards"

- Section 3.6, “Specification for Joining and Attaching Flexible Duct”
  - Section 3.7, “Specification for Supporting Flexible Duct”
  - Sections S6.1, S6.3, S6.4, and S6.5 of Section 9.1, “Casing and Plenum Construction Standards”
- b. All sections of SMACNA’s *Fibrous Glass Duct Construction Standards*<sup>18</sup>
- c. NFPA 90A<sup>19</sup>, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, and NFPA 90B<sup>20</sup>, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*

## 7.2 System Start-Up

**7.2.1 Application.** The requirements of this section apply to the following ventilation systems:

- a. Newly installed air-handling systems
- b. Existing air-handling systems undergoing supply air or outdoor airflow reduction (Only the requirements of Section 7.2.2 shall apply to these altered systems.)
- c. Existing air-handling distribution systems undergoing alterations affecting more than 25% of the floor area served by the systems (Only the requirements of Section 7.2.2 shall apply to these altered systems.)

**7.2.2 Air Balancing.** Ventilation systems shall be balanced in accordance with ASHRAE Standard 111<sup>15</sup> or another applicable national standard for measuring and balancing airflow so as to verify conformance with the total outdoor airflow requirements of this standard.

**7.2.3 Testing of Drain Pans.** To minimize conditions of water stagnation that may result in microbial growth, drain pans shall be field tested under operating conditions that are the most restrictive to condensate flow to demonstrate proper drainage.

**Informative Note:** Above conditions usually occur at full fan airflow for draw-through fans and minimum fan airflow for blow through fans.

**Exception:** Field testing of drain pans is not required if units with factory-installed drain pans have been certified (attested in writing) by the manufacturer for proper drainage when installed as recommended.

**7.2.4 Ventilation System Start-Up.** Ventilation air distribution systems shall be clean of dirt and debris.

**7.2.5 Outdoor Air Dampers.** Prior to occupancy, each ventilation system shall be tested to demonstrate that outdoor air dampers operate in accordance with the system design.

**7.2.6 Documentation.** The following ventilation system documentation shall be provided to the building owner or his/her designee, retained within the building, and made available to the building operating personnel:

- a. An operating and maintenance manual describing basic data relating to the operation and maintenance of ventilation systems and equipment as installed
- b. HVAC controls information consisting of diagrams, schematics, control sequence narratives, and maintenance and/or calibration information

- c. An air balance report documenting the work performed for Section 7.2.2
- d. Construction drawings of record, control drawings, and final design drawings
- e. Design criteria and assumptions

## 8. OPERATIONS AND MAINTENANCE

### 8.1 General

**8.1.1 Application.** The requirements of this section apply to buildings and their ventilation systems and their components constructed or renovated after the adoption date of this section.

**8.1.2 Building Alterations or Change of Use.** When buildings are altered or when changes in building use, occupant category, significant change in occupant density, or other changes inconsistent with system design assumptions are made, the ventilation system design, operation, and maintenance shall be reevaluated and the operations and maintenance (O&M) manual updated as necessary.

**8.2 Operations and Maintenance Manual.** An O&M manual, either written or electronic, shall be developed and maintained on site or in a centrally accessible location for the working life of the applicable ventilation system equipment or components. This manual shall be updated as necessary. The manual shall include the O&M procedures, ventilation system operating schedules and any changes made thereto, final design drawings, maintenance schedules based on manufacturer’s instructions, and the maintenance requirements and frequencies provided in Table 8.2.

**8.3 Ventilation System Operation.** Mechanical and natural ventilation systems shall be operated in a manner consistent with the O&M manual. Systems shall be operated such that spaces are ventilated in accordance with Section 6 during periods of expected occupancy.

**8.4 Ventilation System Maintenance.** The building ventilation system components shall be maintained in accordance with the O&M manual.

## 9. REFERENCES

1. *National Ambient Air Quality Standards*, Code of Federal Regulations, Title 40 Part 50 (40 CFR 50). U.S. Environmental Protection Agency. [www.epa.gov/air/criteria.html](http://www.epa.gov/air/criteria.html), accessed June 27, 2015.
2. *ANSI/SMACNA 016-2012, HVAC Air Duct Leakage Test Manual*, Second Edition, 2012. Chantilly, VA.: Sheet Metal and Air Conditioning Contractors’ Association, Inc. (SMACNA)
3. *UL 181, Factory-Made Air Ducts and Air Connectors*, 11th Edition, 2013. Northbrook, IL: Underwriters’ Laboratories, Inc.
4. *ASTM C 1338-14, Standard Test Method for Determining Fungi Resistance of Insulation Materials and Facings*. West Conshohocken, PA: American Society for Testing and Materials.

**TABLE 8.2 Minimum Maintenance Activity and Frequency for Ventilation System Equipment and Associated Components**

Inspection/Maintenance Task	Frequency*
a. Investigate system for water intrusion or accumulation. Rectify as necessary.	As necessary
b. Verify that the space provided for routine maintenance and inspection of open cooling tower water systems, closed cooling tower water systems, and evaporative condensers is unobstructed.	Monthly
c. Open cooling tower water systems, closed cooling tower water systems, and evaporative condensers shall be treated to limit the growth of microbiological contaminants, including <i>legionella sp.</i>	Monthly
d. Verify that the space provided for routine maintenance and inspection of equipment and components is unobstructed.	Quarterly
e. Check pressure drop and scheduled replacement date of filters and air-cleaning devices. Clean or replace as necessary to ensure proper operation.	Quarterly
f. Check ultraviolet lamp. Clean or replace as needed to ensure proper operation.	Quarterly
g. Visually inspect dehumidification and humidification devices. Clean and maintain to limit fouling and microbial growth. Measure relative humidity and adjust system controls as necessary.	Quarterly
h. Maintain floor drains and trap primer located in air plenums or rooms that serve as air plenums to prevent transport of contaminants from the floor drain to the plenum.	Semiannually
i. Check ventilation and indoor air quality related control systems and devices for proper operation. Clean, lubricate, repair, adjust, or replace as needed to ensure proper operation.	Semiannually
j. Check P-traps in floor drains located in plenums or rooms that serve as air plenums. Prime as needed to ensure proper operation.	Semiannually
k. Check fan belt tension. Check for belt wear and replace if necessary to ensure proper operation. Check sheaves for evidence of improper alignment or evidence of wear and correct as needed.	Semiannually
l. Check variable-frequency drive for proper operation. Correct as needed.	Semiannually
m. Check for proper operation of cooling or heating coil for damage or evidence of leaks. Clean, restore, or replace as required.	Semiannually
n. Visually inspect outdoor air intake louvers, bird screens, mist eliminators, and adjacent areas for cleanliness and integrity; clean as needed; remove all visible debris or visible biological material observed and repair physical damage to louvers, screens, or mist eliminators if such damage impairs the item from providing the required outdoor air entry.	Semiannually
o. Visually inspect natural ventilation openings and adjacent areas for cleanliness and integrity; clean as needed. Remove all visible debris or visible biological material observed and repair physical damage to louvers, and screens if such damage impairs the item from providing the required outdoor air entry. Manual and/or automatic opening apparatus shall be physically tested for proper operation and repaired or replaced as necessary.	Semiannually
p. Verify the operation of the outdoor air ventilation system and any dynamic minimum outdoor air controls.	Annually
q. Check air filter fit and housing seal integrity. Correct as needed.	Annually
r. Check control box for dirt, debris, and/or loose terminations. Clean and tighten as needed.	Annually
s. Check motor contactor for pitting or other signs of damage. Repair or replace as needed.	Annually
t. Check fan blades and fan housing. Clean, repair, or replace as needed to ensure proper operation.	Annually
u. Check integrity of all panels on equipment. Replace fasteners as needed to ensure proper integrity and fit/finish of equipment.	Annually
v. Assess field serviceable bearings. Lubricate if necessary.	Annually
w. Check drain pans, drain lines, and coils for biological growth. Check adjacent areas for evidence of unintended wetting. Repair and clean as needed.	Annually
x. Check for evidence of buildup or fouling on heat exchange surfaces. Restore as needed to ensure proper operation.	Annually

\* Minimum frequencies may be increased or decreased if indicated in the O&M manual.

\*\* National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD.



**TABLE 8.2 Minimum Maintenance Activity and Frequency for Ventilation System Equipment and Associated Components (Continued)**

Inspection/Maintenance Task	Frequency*
y. Inspect unit for evidence of moisture carryover from cooling coils beyond the drain pan. Make corrections or repairs as necessary.	Annually
z. Check for proper damper operation. Clean, lubricate, repair, replace, or adjust as needed to ensure proper operation.	Annually
aa. Visually inspect areas of moisture accumulation for biological growth. If present, clean or disinfect as needed.	Annually
ab. Check condensate pump. Clean or replace as needed.	Annually
ac. Visually inspect exposed ductwork and external piping for insulation and vapor barrier for integrity. Correct as needed.	Annually
ad. Verify the accuracy of permanently mounted sensors whose primary function is outdoor air delivery monitoring, outdoor air delivery verification, or dynamic minimum outdoor air control, such as flow stations at an air handler and those used for demand-control ventilation. A sensor failing to meet the accuracy specified in the O&M manual shall be recalibrated or replaced. Performance verification shall include output comparison to a measurement reference standard consistent with those specified for similar devices in ASHRAE Standard 41.2 or ASHRAE Standard 111 <sup>15</sup> .	5 years
ae. Verify the total quantity of outdoor air delivered by air handlers set to minimum outdoor air mode. If measured minimum airflow rates are less than the design minimum rate documented in the O&M manual, $\pm$ a 10% balancing tolerance, (1) confirm the measured rate does not conform with the provisions of this standard and (2) adjust or modify the air-handler components to correct the airflow deficiency. Ventilation systems shall be balanced in accordance with ASHRAE Standard 111 <sup>15</sup> 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.	5 years
<b>Exception:</b> Units under 2000 cfm (1000 L/s) of supply air are exempt from this requirement.	

\* Minimum frequencies may be increased or decreased if indicated in the O&M manual.

\*\* National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD.

5. *ASTM D3273-12, Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber*. West Conshohocken, PA: American Society for Testing and Materials.
6. *ANSI/AIHA Z9.5-2013, Standard for Laboratory Ventilation*. Fairfax, VA: American Industrial Hygiene Association.
7. *ANSI Z223.1/NFPA-54-2015, National Fuel Gas Code*. Quincy, MA: National Fire Protection Association.
8. *NFPA-31-2011, Standard for the Installation of Oil-Burning Equipment*. Quincy, MA: National Fire Protection Association.
9. *NFPA-211-2013, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*. Quincy, MA: National Fire Protection Association.
10. *UL 1995, Heating and Cooling Equipment*, 4th Edition, 2011. Northbrook, IL: Underwriters Laboratories.
11. *AMCA 500-L-12, Laboratory Methods of Testing Louvers for Rating*. Arlington Heights, IL: Air Movement and Control Association International, Inc.
12. *ANSI/ASHRAE Standard 52.2-2012, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. Atlanta: ASHRAE.
13. *NSF/ANSI 60-2013, Drinking Water Treatment Chemicals—Health Effects*. Ann Arbor, MI: NSF International.
14. *Secondary Direct Food Additives Permitted In Food For Human Consumption*. Code of Federal Regulations, Title 21 Part 173.310 (21 CFR 173.310), *Boiler Water Additives*. U.S. Food and Drug Administration, 2012.
15. *ANSI/ASHRAE Standard 111-2008, Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems*. Atlanta: ASHRAE.
16. *ASHRAE Standard 129-1997 (RA 02), Measuring Air Change Effectiveness*. Atlanta: ASHRAE.
17. *ANSI/SMACNA 006-2006 HVAC Duct Construction Standards—Metal and Flexible*, 3rd Edition, 2005. Chantilly, VA: Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA).
18. *Fibrous Glass Duct Construction Standards*, 7th Edition, 2003. Chantilly, VA: Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA).
19. *NFPA-90A-2012, Standard for the Installation of Air-Conditioning and Ventilating Systems*. Quincy, MA: National Fire Protection Association.
20. *NFPA-90B-2012, Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*. Quincy, MA: National Fire Protection Association.

(This is a normative appendix and is part of the standard.)

## NORMATIVE APPENDIX A MULTIPLE-ZONE SYSTEMS

This appendix presents an alternative procedure for calculating the system ventilation efficiency ( $E_v$ ) that must be used when Table 6.2.5.2 values are not used. In this alternative procedure,  $E_v$  is equal to the lowest calculated value of the zone ventilation efficiency ( $E_{vz}$ ) (see Equation A1.2.1 below).

**Informative Note:** Figure A-1 contains a ventilation system schematic depicting most of the quantities used in this appendix.

### A1. SYSTEM VENTILATION EFFICIENCY

For any multiple-zone recirculating system, the system ventilation efficiency ( $E_v$ ) shall be calculated in accordance with Sections A1.1 through A1.3.

**A1.1 Average Outdoor Air Fraction.** The average outdoor air fraction ( $X_s$ ) for the ventilation system shall be determined in accordance with Equation A1.1.

$$X_s = V_{out}/V_{ps} \quad (A1.1)$$

where the uncorrected outdoor air intake ( $V_{out}$ ) is found in accordance with Section 6.2.5.3, and the system primary airflow ( $V_{ps}$ ) is found at the condition analyzed.

**Informative Note:** For VAV-system design purposes,  $V_{ps}$  is the highest expected system primary airflow at the design condition analyzed. System primary airflow at design is usually less than the sum of design zone primary airflow values because primary airflow seldom peaks simultaneously in all VAV zones.

**A1.2 Zone Ventilation Efficiency.** The zone ventilation efficiency ( $E_{vz}$ ) shall be determined in accordance with Section A1.2.1 or A1.2.2.

**A1.2.1 Single Supply Systems.** For single supply systems, wherein all of the air supplied to each ventilation zone is a mixture of outdoor air and system-level recirculated air, zone ventilation efficiency ( $E_{vz}$ ) shall be determined in accordance with Equation A1.2.1. Examples of single supply systems include constant-volume reheat, single-duct VAV, single-fan dual-duct, and multizone systems.

$$E_{vz} = 1 + X_s - Z_{pz} \quad (A1.2.1)$$

where the average outdoor air fraction for the system ( $X_s$ ) is determined in accordance with Equation A1.1, and the primary

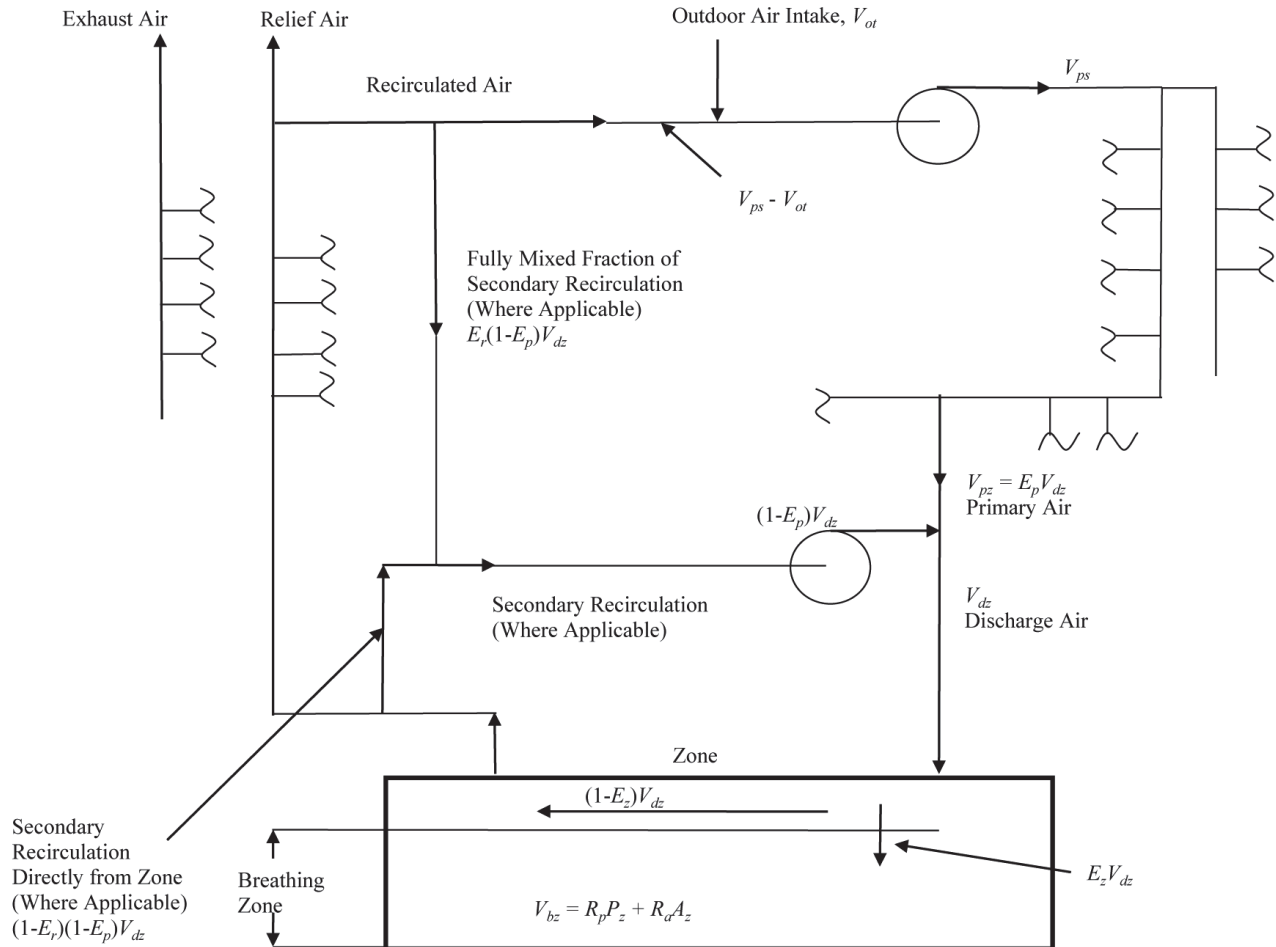


FIGURE A-1 Ventilation system schematic.

outdoor air fraction for the zone ( $Z_{pz}$ ) is determined in accordance with Section 6.2.5.1.

**A1.2.2 Secondary Recirculation Systems.** For secondary recirculation systems wherein all or part of the supply air to each ventilation zone is recirculated air (air that has not been directly mixed with outdoor air) from other zones, zone ventilation efficiency ( $E_{vz}$ ) shall be determined in accordance with Equation A1.2.2-1. Examples of secondary recirculation systems include dual-fan dual-duct and fan-powered mixing-box systems, and systems that include transfer fans for conference rooms.

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a \quad (\text{A1.2.2-1})$$

where system air fractions  $F_a$ ,  $F_b$ , and  $F_c$  are determined in accordance with Equation A1.2.2-2, A1.2.2-3, and A1.2.2-4, respectively.

$$F_a = E_p + (1 - E_p) \times E_r \quad (\text{A1.2.2-2})$$

$$F_b = E_p \quad (\text{A1.2.2-3})$$

$$F_c = 1 - (1 - E_z) \times (1 - E_r) \times (1 - E_p) \quad (\text{A1.2.2-4})$$

Where the zone primary air fraction ( $E_p$ ) is determined in accordance with Equation A1.2.2-5, zone secondary recirculation fraction ( $E_r$ ) is determined by the designer based on system configuration, and zone air distribution effectiveness ( $E_z$ ) is determined in accordance with Section 6.2.2.2.

$$E_p = V_{pz} / V_{dz} \quad (\text{A1.2.2-5})$$

where  $V_{dz}$  is zone discharge airflow.

**Informative Notes:**

1. For plenum return systems with secondary recirculation (e.g., fan-powered VAV with plenum return),  $E_r$  is usually less than 1.0, although values may range from 0.1 to 1.2, depending upon the location of the ventilation zone relative to other zones and the air handler. For ducted return systems with secondary recirculation (e.g., fan-powered VAV with ducted return),  $E_r$  is typically 0.0, while for those with system-level recirculation (e.g., dual-fan dual-duct systems with ducted return),  $E_r$  is typically 1.0. For other system types,  $E_r$  is typically 0.75.
2. For single-zone and single-supply systems,  $E_p$  is 1.0.

**A1.3 System Ventilation Efficiency.** The system ventilation efficiency shall equal the lowest zone ventilation efficiency among all ventilation zones served by the air handler in accordance with Equation A1.3.

$$E_v = \text{minimum } (E_{vz}) \quad (\text{A1.3})$$

## A2. DESIGN PROCESS

The system ventilation efficiency and, therefore, the outdoor air intake flow for the system ( $V_{ot}$ ) determined as part of the design process are based on the design and minimum expected supply airflows to individual ventilation zones as well as the design outdoor air requirements to the zones. For VAV system design purposes, zone ventilation efficiency ( $E_{vz}$ ) for each ventilation zone shall be found using the mini-

mum expected zone primary airflow ( $V_{pz}$ ) and using the highest expected system primary airflow ( $V_{ps}$ ) at the design condition analyzed.

**Informative Note:** Increasing the zone supply airflow values during the design process, particularly to the critical zones requiring the highest fraction of outdoor air, reduces the system outdoor air intake flow requirement determined in the calculation.

**A2.1 Selecting Zones for Calculation.** Zone ventilation efficiency ( $E_{vz}$ ) shall be calculated for all ventilation zones.

**Exception:** Because system ventilation efficiency ( $E_v$ ) is determined by the minimum value of the zone ventilation efficiency ( $E_{vz}$ ) in accordance with Equation A1.3, calculation of  $E_{vz}$  is not required for any ventilation zone that has an  $E_{vz}$  value that is equal to or larger than that of the ventilation zone for which a calculation has been made.

**Informative Note:** The value of  $E_{vz}$  for a ventilation zone will be equal to or larger than that for another ventilation zone if all of the following are true relative to the other ventilation zone:

- a. Floor area per occupant ( $A_z/P_z$ ) is no lower.
- b. Minimum zone discharge airflow rate per unit area ( $V_{dz}/A_z$ ) is no lower.
- c. Primary air fraction ( $E_p$ ) is no lower.
- d. Zone air distribution effectiveness ( $E_z$ ) is no lower.
- e. Area outdoor air rate ( $R_a$ ) is no higher.
- f. People outdoor air rate ( $R_p$ ) is no higher.

## A3. SYMBOLS

$A_z$	<b>zone floor area:</b> the net occupiable floor area of the ventilation zone, ft <sup>2</sup> (m <sup>2</sup> ).
$D$	<b>occupant diversity:</b> the ratio of the system population to the sum of the zone populations.
$E_p$	<b>primary air fraction:</b> the fraction of primary air in the discharge air to the ventilation zone
$E_r$	<b>secondary recirculation fraction:</b> in systems with secondary recirculation of return air, the fraction of secondary recirculated air to the zone that is representative of average system return air rather than air directly recirculated from the zone.
$E_v$	<b>system ventilation efficiency:</b> the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in the ventilation-critical zone, which requires the largest fraction of outdoor air in the primary airstream. $E_v$ shall be determined in accordance with Section 6.2.5.2 or Section A1.
$E_{vz}$	<b>zone ventilation efficiency:</b> the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in any particular ventilation zone.
$E_z$	<b>zone air distribution effectiveness:</b> a measure of the effectiveness of supply air distribution to the breathing zone. $E_z$ is determined in accordance with Section 6.2.2.2.

$F_a$	<b>supply air fraction:</b> the fraction of supply air to the ventilation zone that includes sources of air from outside the zone.	$V_{ot}$	<b>outdoor air intake flow:</b> see Sections 6.2.3, 6.2.4, and 6.2.5.4.
$F_b$	<b>mixed-air fraction:</b> the fraction of supply air to the ventilation zone from fully mixed primary air.	$V_{ou}$	<b>uncorrected outdoor air intake:</b> see Section 6.2.5.3.
$F_c$	<b>outdoor air fraction:</b> the fraction of outdoor air to the ventilation zone that includes sources of air from outside the zone.	$V_{oz}$	<b>zone outdoor airflow:</b> see Section 6.2.2.3.
$P_s$	<b>system population:</b> the simultaneous number of occupants in the area served by the ventilation system.	$V_{ps}$	<b>system primary airflow:</b> the total primary airflow supplied to all zones served by the system from the air-handling unit at which the outdoor air intake is located.
$P_z$	<b>zone population:</b> see Section 6.2.2.1.	$V_{pz}$	<b>zone primary airflow:</b> see Section 6.2.5.1.
$R_a$	<b>area outdoor air rate:</b> see Section 6.2.2.1.	$X_s$	<b>average outdoor air fraction:</b> at the primary air handler, the fraction of outdoor air intake flow in the system primary airflow.
$R_p$	<b>people outdoor air rate:</b> see Section 6.2.2.1.		
$V_{bz}$	<b>breathing zone outdoor airflow:</b> see Section 6.2.2.1.	$Z_{pz}$	<b>primary outdoor air fraction:</b> the outdoor air fraction required in the primary air supplied to the ventilation zone prior to the introduction of any secondary recirculation air.
$V_{dz}$	<b>zone discharge airflow:</b> the expected discharge (supply) airflow to the zone that includes primary airflow and secondary recirculated airflow, cfm (L/s).		

(This is a normative appendix and is part of the standard.)

## NORMATIVE APPENDIX B SEPARATION OF EXHAUST OUTLETS AND OUTDOOR AIR INTAKES

### B1. GENERAL

This appendix presents an alternative procedure for determining separation distance between outdoor air intakes and exhaust air and vent outlets. This analytical method can be used instead of Table 5.5.1.

Exhaust air and vent outlets, as defined in Table 5.5.1, shall be located no closer to outdoor air intakes, and operable windows, skylights, and doors, both those on the subject property and those on adjacent properties, than the minimum separation distance ( $L$ ) specified in this section. The distance ( $L$ ) is defined as the shortest “stretched string” distance measured from the closest point of the outlet opening to the closest point of the outdoor air intake opening or operable window, skylight, or door opening, along a trajectory as if a string were stretched between them.

**B1.1 Application.** Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45<sup>5</sup> and ANSI/AIHA Z9.5<sup>6</sup>. Nonlaboratory exhaust outlets and outdoor air intakes or other openings shall be separated in accordance with the following.

**B1.2 Outdoor Air Intakes.** The minimum separation distance between exhaust air/vent outlets as defined in Table 5.5.1 and outdoor air intakes to mechanical ventilation systems or operable windows, skylights, and doors that are required as part of natural ventilation systems shall be equal to distance ( $L$ ) determined in accordance with Section B2.

**Exception:** Separation distances do not apply when exhaust and outdoor air intake systems are controlled such that they cannot operate simultaneously.

**B1.3 Other Building Openings.** The minimum separation distance between building exhaust air/vent outlets as defined in Table 5.5.1 and operable openings to occupiable spaces shall be half of the distance ( $L$ ) determined in accordance with Section B2. The minimum separation distance between either Class 3, Class 4, cooling tower, or combustion appliance/equipment exhaust air/vent outlets and operable openings to occupiable spaces shall be equal to the distance ( $L$ ) determined in accordance with Section B2.

**B1.4 Additional Limitations for Noxious or Dangerous Air.** The minimum separation distance between exhausts located less than 65 ft (20 m) vertically below outdoor air intakes or operable windows and doors shall be equal to a horizontal separation only as determined in accordance with Section B2; no credit may be taken for any vertical separation.

**B1.5 Equipment Wells.** Exhaust air outlets that terminate in an equipment well that also encloses an outdoor air intake shall meet the separation requirements of this section and, in addition, shall either

- terminate at or above the highest enclosing wall and discharge air upward at a velocity exceeding 1000 fpm (5 m/s) or
- terminate 3 ft (1 m) above the highest enclosing wall (with no minimum velocity).

**TABLE B2-1 Minimum Separation Distance**

Exhaust Air Class (See Section 5.16)	Separation Distance, $L$ , ft (m)
Significant contaminant or odor intensity (Class 3)	15 (5)
Noxious or dangerous particles (Class 4)	30 (10)

**TABLE B2-2 Minimum Dilution Factors**

Exhaust Air Class (See Section 5.16)	Dilution Factor (DF)
Significant contaminant or odor intensity (Class 3)	15
Noxious or dangerous particles (Class 4)	50*

\*Does not apply to fume hood exhaust. See Section B1.1.

**Exception:** Exhaust air designated as Class 1 or Class 2.

**B1.6 Property Lines.** The minimum separation distance between exhaust air/vent outlets and property lines shall be half of the distance ( $L$ ) determined in accordance with Section B2.

**Exception:** For Class 3, Class 4, or combustion appliance/equipment exhaust air, where the property line abuts a street or other public way, no minimum separation is required if exhaust termination is at least 10 ft (3 m) above grade.

### B2. DETERMINING DISTANCE $L$

The minimum separation distance ( $L$ ) shall be determined using one of the following three approaches:

- A value of  $L$  in Table B2-1 shall be used.
- The value of  $L$  shall be determined using Equation B2-1 or B2-2.

$$L = 0.09 \times \sqrt{Q} \times (\sqrt{DF} - U/400) \text{ in feet} \quad (\text{I-P}) \quad (\text{B2-1})$$

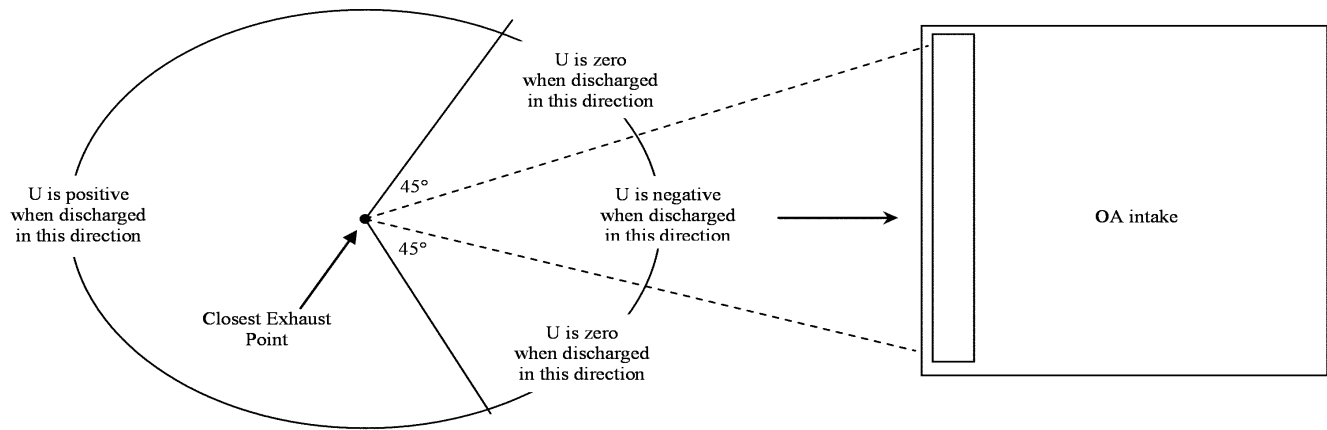
$$L = 0.04 \times \sqrt{Q} \times (\sqrt{DF} - U/2) \text{ in metres} \quad (\text{SI}) \quad (\text{B2-2})$$

where

$Q$  = exhaust airflow rate, cfm (L/s). For gravity vents, such as plumbing vents, use an exhaust rate of 150 cfm (75 L/s). For flue vents from fuel-burning appliances, assume a value of 250 cfm per million Btu/h (0.43 L/s per kW) of combustion input (or obtain actual rates from the combustion appliance manufacturer.

$U$  = exhaust air discharge velocity, fpm (m/s). As shown in Figure B2-1,  $U$  shall be determined using Table B2-3.

$DF$  = dilution factor, which is the ratio of outdoor airflow to entrained exhaust airflow in the outdoor air intake. The minimum dilution factor shall be determined as a function of exhaust air class in Table B2-2.



**FIGURE B2-1 Exhaust air discharge velocity ( $U$ ).**

**TABLE B2-3 Exhaust Air Discharge Velocity**

Exhaust Direction/Configuration	Exhaust Air Discharge Velocity ( $U$ ) Modifier
Exhaust is directed away from the outdoor air intake at an angle that is greater than 45 degrees from the direction of a line drawn from the closest exhaust point to the edge of the intake	$U$ given a positive value
Exhaust is directed toward the intake bounded by lines drawn from the closest exhaust point to the edge of the intake	$U$ given a negative value
Exhaust is directed at an angle between the two above cases	$U$ is zero
Vents from gravity (atmospheric) fuel-fired appliances, plumbing vents, and other nonpowered exhausts, or if the exhaust discharge is covered by a cap or other device that dissipates the exhaust airstream	$U$ is zero
Hot gas exhausts such as combustion products if the exhaust stream is aimed directly upward and unimpeded by devices such as flue caps or louvers	Add 500 fpm (2.5 m/s) upward velocity to $U$

For exhaust air composed of more than one class of air, the dilution factor shall be determined by averaging the dilution factors by the volume fraction of each class using Equation B2-3:

$$DF = \sum (DF_i \times Q_i) / \sum Q_i \quad (B2-3)$$

where

$DF_i$  = dilution factor from Table B2-2 for class  $i$  air.

$Q_i$  = volumetric flow rate of class  $i$  air in the exhaust airstream.

- c. When the above options do not represent the proposed design, then an exceptional calculation method shall be used to calculate the value of  $L$  if approved by the authority having jurisdiction. It must be shown that the proposed design will result in dilution factors that are not less than those specified in Table B2-2.

**(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 ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objections on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## INFORMATIVE APPENDIX C SUMMARY OF SELECTED AIR QUALITY GUIDELINES

If particular contaminants are of concern, or if the IAQ Procedure is to be used, acceptable indoor concentrations and exposures are needed for the particular contaminants. When using this procedure, these concentration and exposure values need to be documented and justified by reference to a cognizant authority as defined in the standard. Such guidelines or other limiting values can also be useful for diagnostic purposes. At present, no single organization develops acceptable concentrations or exposures for all indoor air contaminants, nor are values available for all contaminants of potential concern. A number of organizations offer guideline values for selected indoor air contaminants. These values have been developed primarily for ambient air, occupational settings, and, in some cases, for residential settings. They should be applied with an understanding of their basis and applicability to the indoor environment of concern. If an acceptable concentration or exposure has not been published for a contaminant of concern, a value may be derived through review of the toxicological and epidemiological evidence using appropriate consultation. However, the evidence with respect to health effects is likely to be insufficient for many contaminants. At present, there is no quantitative definition of acceptable IAQ that can necessarily be met by measuring one or more contaminants.

Table C-1 presents selected standards and guidelines used in Canada, Germany, Europe, and the United States for acceptable concentrations of substances in ambient air, indoor air, and industrial workplace environments. These values are issued by cognizant authorities and have not been developed or endorsed by ASHRAE. The table is presented only as background information when using the IAQ Procedure. Specialized expertise should be sought before selecting a value for use in estimating outdoor airflow rates using the IAQ Procedure or for building design or diagnostics purposes. Meeting one, some, or all of the listed values does not ensure that acceptable IAQ (as defined in this standard) will be achieved.

Tables C-2 and C-3 list concentration values of interest for selected contaminants as general guidance for building design, diagnostics, and ventilation system design using the IAQ Procedure. The values in the table are based on cognizant authorities and studies reported in peer-reviewed scientific publications; ASHRAE does not recommend their adoption as regulatory values, standards, or guidelines. The tables are presented as further background when using the IAQ Procedure. Consultation should be sought before selecting a particular value for use in calculating ventilation using the IAQ Procedure. Meeting one, some, or all of the listed values does not ensure that acceptable IAQ will be achieved.

Selection of a specific target concentration and exposure is best made by a team with wide experience in toxicology, industrial hygiene, and exposure assessment. As they review the specific concentrations listed in Tables C-1, C-2, and C-3, or others taken from other sources, designers should be mindful of the following:

- Standards and guidelines are developed for different purposes and should be interpreted with reference to the setting and purpose for which they were developed compared to that to which they are being applied.
- Not all standards and guideline values recognize the presence of susceptible groups or address typical populations found in occupancies listed in this standard.
- Most standards and guidelines do not consider interactions between and among various contaminants of concern.
- The assumptions and conditions set forth by the standard or guideline may not be met in the space or for the occupants being considered (such as an 8-hour day, 40-hour work week).

When many chemicals are present in the air, as they almost always are in indoor air, then some way of addressing potential additive effects is warranted. The ACGIH guidance on the subject instructs that when two or more substances acting on the "...same organ system are present, their combined effect, rather than that of either individually, should be given primary consideration." <sup>C-1</sup> Information on affected organs is readily available on the websites of the cited references for ACGIH, OEHHA, and ATSDR. If no contradictory information is available, the effects of the different substances "should be considered as additive." A formula is given wherein the ratios of the concentrations of each substance with the same health-related endpoint to the threshold-limit value for each substance are added. If the sum of all these ratios exceeds unity, then it is considered that the concentration value has been exceeded.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n}$$

where

$C_i$  = airborne concentration of the substance

$T_i$  = threshold-limit value of that substance

### C1. GUIDELINE VALUES FOR INDUSTRIAL ENVIRONMENTS

ACGIH threshold limit values, or TLVs<sup>®</sup>, have been applied to industrial workplace air contaminants <sup>C-1</sup> (Reference C-2 is the German counterpart). The ACGIH TLVs represent the maximum acceptable 8-hour, time-weighted average (TWA); 15-minute short-term exposure limit (STEL); and instantaneous (ceiling) case limits. It is a source of concentration limits for many chemical substances and physical agents for industrial use. In light of the constantly changing state of knowledge, the document is updated annually. It cautions the user, "The values listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommenda-

tions to assist in the control of potential health hazards and for no other use.”

Caution must be used in directly extending the ACGIH TLVs or other workplace guidelines to spaces covered by this standard and to population groups other than workers. Industrial health practice attempts to limit worker exposure to injurious substances at levels that do not interfere with the industrial work process and do not risk the workers’ health and safety. There is not an intention to eliminate all effects, such as unpleasant smells or mild irritation. Further, the health criteria are not uniformly derived for all contaminants. Irritation, narcosis, and nuisance or other forms of stress are not uniformly considered as the basis for the concentration limits. This is because different organizations use different end points and different contaminants have more or less information available on diverse end points of interest. The target population is also different from the occupants found in the spaces covered by this standard. Healthy industrial workers tend to change jobs or occupations if an exposure becomes intolerable. In contrast, workers in commercial environments such as offices often do not expect elevated concentrations of potentially harmful substances in their work environments. Also, monitoring programs are unlikely to be in place, as may be the case with industrial workplaces. In addition, the general population may have less choice about where they spend most of their time and includes those who may be more sensitive, such as children, asthmatics, allergic individuals, the sick, and the elderly.

## **C2. GUIDELINES FOR SUBSTANCES IN OUTDOOR AIR**

Guidelines have been developed for outdoor air for a number of chemicals and metals, as shown in many of the references. These values, including some for metals, may be appropriate for some indoor environments, but they should be applied only after appropriate consultation. These guidelines also provide guidance concerning the quality of outdoor air if there is suspicion that outdoor air may be contaminated with specific substances or if there is a known source of contamination nearby<sup>C-3</sup>.

## **C3. REGULATION OF OCCUPATIONAL EXPOSURE TO AIRBORNE CONTAMINANTS**

Regulations of occupational exposure to workplace hazards are based on the results of accumulated experience with worker health and toxicological research and carefully evaluated by groups of experts. Effects are examined in relation to exposure to the injurious substance. Exposure is defined as the mathematical product of the concentration of the contaminant and the time during which a person is exposed to this concentration. Because concentration may vary with time, exposure is typically calculated across the appropriate averaging time, expressed as a TWA concentration, STEL, or ceiling limit. Regulations of the U.S. Occupational Safety and Health Administration (OSHA) are TWAs in most cases.

Industrial exposures are regulated on the basis of a 40-hour workweek with 8- to 10-hour days. During the remainder of the time, exposure is anticipated to be substantially lower for the contaminants of concern. Application of indus-

trial exposure limits would not necessarily be appropriate for other indoor settings, occupancies, and exposure scenarios. However, for certain contaminants that lack exposure limits for a specific nonindustrial target population, substantial downward adjustments to occupational limits have sometimes been used.

## **C4. SUBSTANCES LACKING GUIDELINES AND STANDARDS**

For indoor contaminants for which an acceptable concentration and exposure value has not been established by a cognizant authority, one approach has been to assume that some fraction of TLV is applicable and would not lead to adverse health effects or complaints in general populations. This approach should not be used without first assessing its suitability for the contaminant of concern. In any event, if appropriate standards or guidelines do not exist, expertise must be sought or research needs to be conducted to determine contaminant concentrations and exposures that are acceptable.

## **C5. SUBJECTIVE EVALUATION**

Indoor air often contains complex mixtures of contaminants of concern, such as environmental tobacco smoke<sup>C-30,C-31</sup>, infectious and allergenic biological aerosols<sup>C-32</sup>, and emissions of chemicals from commercial and consumer products. Precise quantitative treatment of these contaminants can be difficult or impossible in most cases. Chemical composition alone may not always be adequate to reliably predict the reaction of building occupants exposed to most common mixtures of substances found in indoor air. There are many toxicological endpoints used in assessing the effects from exposure to air contaminants.

Irritation of mucosal tissue, such as that found in the human nose, eyes, and the upper airways, is one of the endpoints often used in assessing short-term exposure to air contaminants. These irritation responses can occur after the irritant receptor is exposed to nonreactive compounds, to reactive compounds with a different pattern of dose-response relationships, and through allergic and other immunologic effects for which dose-response relationships have not been well defined. Susceptible populations—i.e., individuals with atopy (“allergies”)—may report irritation at lower levels of exposures than individuals without allergies. Other susceptible populations, such as the elderly and the young, may differ from healthy adults in their response to irritating and odorous substances.

To some degree, adequacy of control may rest upon subjective evaluation. Panels of observers have been used to perform subjective evaluation of IAQ in buildings. Many contaminants have odors or are irritants that may be detected by human occupants or visitors to a space. Generally, the air can be considered acceptably free of annoying contaminants if 80% of a panel consisting of a group of untrained subjects exposed to known concentrations of contaminants under representative controlled conditions of use and occupancy deems the air not to be objectionable.

When performing a subjective evaluation, an observer should enter the space in the manner of a normal visitor and should render a judgment of acceptability within 15 seconds.



Each observer should make the evaluation independently of other observers and without influence from a panel leader. Users of subjective evaluation methods are cautioned that they only test odor and sensory responses. Some harmful contaminants will not be detected by such tests. Carbon monoxide and radon are two examples of odorless contaminants that pose significant health risks. To evaluate the acceptability of adapted persons (occupants), an observer should spend at least six minutes in the space before rendering a judgment of acceptability<sup>C-29</sup>.

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## Guide for Using TABLE C-1

The substances listed in Table C-1 are common air contaminants in industrial and nonindustrial environments. The values summarized in this table are from various sources with diverse procedures and criteria for establishing the values. Some are for industrial environments (OSHA, MAK, NIOSH, ACGIH), some are for outdoor environments (NAAQS), and others are general (WHO) or indoor residential environment-related (Canadian) values. The following explanations are intended to assist the reader by providing a brief description of the criteria each agency used in adopting its guideline values.

- NAAQS: Outdoor air standards developed by the U.S. EPA under the Clean Air Act. By law, the values listed in these regulations must be reviewed every five years. These concentrations are selected to protect not only the general population but also the most sensitive individuals.
- OSHA: Enforceable maximum exposures for industrial environments developed by OSHA (U.S. Department of Labor) through a formal rule-making process. Once an exposure limit has been set, levels can be changed only through reopening the rule-making process. These permissible exposure limits (PELs) are not selected to protect the most sensitive individuals.
- MAK: Recommended maximum exposures for industrial environments developed by the Deutsche Forschungs Gemeinschaft, a German institution similar to the U.S. National Institutes of Health and NIOSH. Levels are set on a regular basis, with annual reviews and periodic republication of criteria levels. These levels are enforceable in Germany and are not selected to protect the most sensitive individuals.
- Canadian: Recommended maximum exposures for residences developed in 1987 and reaffirmed in 1995 by a committee of provincial members convened by the federal government to establish consensus guideline-type levels. A revised version is being considered. These are not intended to be enforced.
- WHO/Europe: Environmental (nonindustrial) guidelines developed in 1987 and updated in 1999 by the WHO Office for Europe (Denmark). Intended for application both to indoor and outdoor exposure.
- NIOSH: Recommended maximum exposure guidelines for industrial environments are developed by NIOSH (Centers for Disease Control) and published in a series of criteria documents. NIOSH criteria documents contain both a review of the literature and a recommended exposure limit (REL) guideline. These are not enforceable, are not reviewed regularly, and are not selected to protect the most sensitive individuals. In some cases, they are set at levels above those deemed protective of health because commonly available industrial hygiene practice does not reliably detect the substances at lower levels. (Note that methods used in nonindustrial settings are often more sensitive than NIOSH methods for industrial hygiene measurements.)
- ACGIH: Recommended maximum exposures for industrial environments developed by ACGIH's Threshold Limit Values (TLVs) Committee. The committee reviews the scientific literature and recommends exposure guidelines. The assumptions are for usual industrial working conditions, 40-hour weeks, and single exposures. Surveillance practices for both exposures and biological responses are often in place in the work environments where these levels are used. These levels are not selected to protect the most sensitive individuals. About half of the TLVs are intended to protect against irritation. Published studies have shown that many of the TLVs intended to protect against irritation actually represent levels where some or all of the study subjects did report irritation <sup>C-33, C-34</sup>.

The table is not inclusive of all contaminants in indoor air, and achieving the listed indoor concentrations for all of the listed substances does not ensure odor acceptability, avoidance of sensory irritation, or all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentrations.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable IAQ with regard to comfort (sensory irritation), odors, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature.

**TABLE C-1 Comparison of Regulations and Guidelines Pertinent to Indoor Environments<sup>a</sup>**  
(The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Enforceable and/or Regulatory Levels				Nonenforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. C-4)	OSHA (Ref. C-5)	MAK (Ref. C-2)	Canadian (Ref. C-8)	WHO/Europe (Ref. C-11)	NIOSH (Ref. C-13)	ACGIH (Ref. C-1)
Carbon dioxide		5000 ppm	5000 ppm 10,000 ppm [1 h]	3500 ppm [L]		5000 ppm 30,000 ppm [15 min]	5000 ppm 30,000 ppm [15 min]
Carbon monoxide <sup>c</sup>	9 ppm <sup>g</sup> 35 ppm [1 h] <sup>g</sup>	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 h] 25 ppm [1 h]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 h] 10 ppm [8 h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde <sup>h</sup>		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm <sup>i</sup>	0.1 ppm [L] 0.05 ppm [L] <sup>b</sup>	0.1 mg/m <sup>3</sup> (0.081 ppm) [30 min] <sup>p</sup>	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 µg/m <sup>3</sup> [3 months]	0.05 mg/m <sup>3</sup>	0.1 mg/m <sup>3</sup> 1 mg/m <sup>3</sup> [30 min]	Minimize exposure	0.5 µg/m <sup>3</sup> [1 yr]	0.050 mg/m <sup>3</sup>	0.05 mg/m <sup>3</sup>
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 h]	0.1 ppm[1 h] 0.02 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 h] <sup>g</sup> 0.08 ppm	0.1 ppm	j	0.12 ppm [1 h]	0.064 ppm (120 µg/m <sup>3</sup> ) [8 h]	0.1 ppm [C]	0.05 ppm <sup>k</sup> 0.08 ppm <sup>l</sup> 0.1 ppm <sup>m</sup> 0.2 ppm <sup>n</sup>
Particles <sup>e</sup> <2.5 µm MMAD <sup>d</sup>	15 µg/m <sup>3</sup> [1 yr] <sup>o</sup> 35 µg/m <sup>3</sup> [24 h] <sup>o</sup>	5 mg/m <sup>3</sup>	1.5 mg/m <sup>3</sup> for <4 µm	0.1 mg/m <sup>3</sup> [1 h] 0.040 mg/m <sup>3</sup> [L]			3 mg/m <sup>3</sup> [C]
Particles <sup>e</sup> <10 µm MMAD <sup>d</sup>	150 µg/m <sup>3</sup> [24 h] <sup>o</sup>		4 mg/m <sup>3</sup>				10 mg/m <sup>3</sup> [C]
Radon				800 Bq/m <sup>3</sup> [1 yr]			
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 h] <sup>g</sup>	5 ppm	0.5 ppm 1 ppm <sup>i</sup>	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total particles <sup>e</sup>		15 mg/m <sup>3</sup>					

a. Numbers in brackets [ ] refer to either a ceiling or to averaging times of less than or greater than eight hours (min = minutes; h = hours; y = year; C = ceiling; L = long-term). Where no time is specified, the averaging time is eight hours.  
b. Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm. Although the epidemiological studies conducted to date provide little convincing evidence that formaldehyde is carcinogenic in human populations, because of this potential, indoor levels should be reduced as much as possible.

c. As one example regarding the use of values in this table, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for nonindustrial, as opposed to industrial, exposure are substantially lower. These lower concentrations (in other words, the ambient air quality standards, which are required to consider populations at highest risk) are set to protect the most sensitive subpopulation, individuals with pre-existing heart conditions.

d. MMAD = mass median aerodynamic diameter in microns (micrometers). Less than 3.0 µm is considered respirable; less than 10 µm is considered inhalable.

e. Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline silica, known carcinogens, or other particles known to cause significant adverse health effects.

f. See Table C-2 for the U.S. EPA guideline.

g. Not to be exceeded more than once per year

h. The U.S. Department of Housing and Urban Development adopted regulations concerning formaldehyde emissions from plywood and particleboard intended to limit the airborne concentration of formaldehyde in manufactured homes to 0.4 ppm. (24 CFR Part 3280, HUD Manufactured Home Construction and Safety Standards). In addition, California Air Resources Board Regulation §93120, entitled "Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products" has specific chamber-based requirements for composite wood products sold in California C-47.

i. Never to be exceeded

j. Carcinogen, no maximum values established

k. TLV for heavy work

l. TLV for moderate work

m. TLV for light work

n. TLV for heavy, moderate, or light workloads (less than or equal to two hours)

o. 62FR38652 - 38760, July 16, 1997

p. Epidemiological studies suggest a causal relationship between exposure to formaldehyde and nasopharyngeal cancer, although the conclusion is tempered by the small numbers of observed and expected cases. There are also epidemiological observations of an association between relatively high occupational exposures to formaldehyde and sinonasal cancer.

## Guide for Using TABLE C-2

The substances listed in Table C-2 are common air contaminants of concern in nonindustrial environments. The target concentrations that have been set or proposed by various national or international organizations concerned with health and comfort effects of outdoor and indoor air are listed for reference only. The table is not inclusive of all contaminants in indoor air, and achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentrations.

Health or comfort effects and exposure periods that are the basis for the guideline levels are listed in the “comments” column. For design, the goal should be to meet the guideline levels continuously during occupancy because people spend the great majority of their time indoors.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable IAQ with regard to comfort (sensory irritation), odors, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature. (Table C-2 summarizes some of this literature.)

**TABLE C-2 Concentration of Interest for Selected Contaminants**

(Note: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]. The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Contaminant	Sources	Concentrations of Interest	Comments	References
Carbon Monoxide (CO)	Leaking vented combustion appliances Unvented combustion appliances Parking garages Outdoor air	9 ppm (8 h)	Based on effects on persons with coronary artery disease, average exposure for eight hours. Sustained indoor concentrations exceeding outdoor concentrations may merit further investigation. Many carbon monoxide measuring instruments have limited accuracy at low levels. Sources—burning of gasoline, natural gas, coal, oil, etc. (Note: CO is unlikely to be the only contaminant of concern in parking garages or other spaces where vehicles operate.) Health effects—reduces ability of blood to bring oxygen to body cells and tissues; cells and tissues need oxygen to work. Carbon monoxide may be particularly hazardous to people who have heart or circulatory problems and people who have damaged lungs or breathing passages.	C-4 [c] C-9 [m]
Formaldehyde (HCHO)	Pressed-wood products Furniture and furnishings	0.1 mg/m <sup>3</sup> (0.081 ppm) (30 min)  27 ppb (8 h)	Based on irritation of sensitive people, 30-minute exposure (WHO)  Established as a never-to-exceed guideline to avoid irritant effects in sensitive individuals. Does not protect against formaldehyde’s potential carcinogenicity (California Air Resources Board).	C-11 [c] C-9, 26 [m]  C-16
		45 ppb (55 µg/m <sup>3</sup> ) (1 h) 7.3 ppb (9 µg/m <sup>3</sup> ) (8 h)	Acute and 8-hour noncancer Reference Exposure Levels (RELs) developed based on current scientific database (Cal-EPA, OEHHA).  Health effects—Acute and chronic inhalation exposure to formaldehyde in humans can result in eye, nose, and throat irritation, respiratory symptoms, exacerbation of asthma, and sensitization. Human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. In 2004, the International Agency for Research on Cancer (IARC) concluded that “ <i>formaldehyde is carcinogenic to humans (Group 1)</i> , on the basis of <i>sufficient evidence</i> in humans and <i>sufficient evidence</i> in experimental animals.”	C-36  C-19, 20, 36, 40
		16 ppb	FEMA Procurement Specification for Mobile Homes	C-48

a. USEPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

### Conversion Factors C-17

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

$$\text{ppm} \times \text{molecular weight}/24,450 = \text{mg/L}$$

$$\text{ppm} \times \text{molecular weight}/0.02445 = \mu\text{g}/\text{m}^3$$

$$\text{ppm} \times \text{molecular weight}/24.45 = \text{mg}/\text{m}^3$$

$$\text{ppm} \times \text{molecular weight} \times 28.3/24,450 = \text{mg}/\text{ft}^3$$

**TABLE C-2 Concentration of Interest for Selected Contaminants (Continued)**  
 (Note: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]. The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Contaminant	Sources	Concentrations of Interest	Comments	References
Lead (Pb)	Paint dust Outdoor air	1.5 µg/m <sup>3</sup>	Based on adverse effects on neuropsychological functioning of children, average exposure for three months (WHO): 0.5–1 µg/m <sup>3</sup> for 1 year. Sources—leaded gasoline (being phased out), paint (houses, cars), smelters (metal refineries), manufacture of lead storage batteries. Health effects—brain and other nervous system damage; children are at special risk. Some lead-containing chemicals cause cancer in animals. Lead causes digestive and other health problems. Environmental effects—Lead can harm wildlife.	C-4 [c] C-4 [m] C-18
Nitrogen Dioxide (NO <sub>2</sub> )	Leaking vented combustion appliances Unvented combustion appliances Outdoor air Parking garages	100 µg/m <sup>3</sup>	Based on providing protection against adverse respiratory effects, average exposure for one year.  Sources—burning of gasoline, natural gas, coal, oil, etc. Cars are an important source of NO <sub>2</sub> outdoors and cooking and water- and space-heating devices are important sources indoors. Health effects—lung damage, illnesses of breathing passages and lungs (respiratory system). Environmental effects—Nitrogen dioxide is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can reduce visibility. Property damage—Acid aerosols can eat away stone used on buildings, statues, monuments, etc. 24-hour average to prevent high exposures during use of combustion appliances such as space-heating devices and gas stoves.	C-4 [c] C-9 [m] C-18
Odors	Occupants VOC sources (including fungal sources such as mold) Cooking, food processing, sewage, biowaste facilities, etc.	Predicted (or measured) acceptability to 80% or more of occupants or visitors	CO <sub>2</sub> concentration can be used as a surrogate for occupant odors (odorous bioeffluents). See Informative Appendix D for a discussion of indoor CO <sub>2</sub> levels and ventilation rates. For sources other than people, source control is recommended.	C-12, 24, 29, 30 [c] C-9 (CO <sub>2</sub> ), C-15 (odor) [m]
Ozone (O <sub>3</sub> )	Electrostatic appliances Office machines Ozone generators Outdoor air	100 µg/m <sup>3</sup> (50 ppb)	Based on 25% increase in symptom exacerbations among adults or asthmatics (normal activity), eight-hour exposure (WHO); continuous exposure (FDA). Ozone present at levels below the concentration of interest may contribute to the degradation of indoor air quality directly and by reacting with other contaminants in the indoor space. Ground-level ozone is the principal component of smog. Sources—outdoors, from chemical reaction of pollutants, VOCs, and NO <sub>x</sub> ; indoors, from photocopiers, laser printers, ozone generators, electrostatic precipitators, and some other air cleaners. Health effects—breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, reduced resistance to colds and other infections. May speed up aging of lung tissue. Environmental effects—Outdoors, ozone can damage plants and trees; smog can cause reduced visibility. Property damage—Indoors and outdoors, ozone damages natural and synthetic rubbers, plastics, fabrics, etc.	C-6, 11 [c] C-6 [m] C-18
Particles (PM <sub>2.5</sub> )	Combustion products, cooking, candles, incense, resuspension, outdoor air, diesel exhaust, and parking garages	15 µg/m <sup>3</sup>		C-4

a. USEPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

#### Conversion Factors C-17

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

$$\text{ppm} \times \text{molecular weight}/24,450 = \text{mg/L}$$

$$\text{ppm} \times \text{molecular weight}/0.02445 = \mu\text{g}/\text{m}^3$$

$$\text{ppm} \times \text{molecular weight}/24.45 = \text{mg}/\text{m}^3$$

$$\text{ppm} \times \text{molecular weight} \times 28.3/24,450 = \text{mg}/\text{ft}^3$$

**TABLE C-2 Concentration of Interest for Selected Contaminants (Continued)**

(Note: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m]. The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Contaminant	Sources	Concentrations of Interest	Comments	References
Particles (PM <sub>10</sub> )	Dust Smoke Deteriorating materials Outdoor air	50 µg/m <sup>3</sup>	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for one year, no carcinogens. Indoor concentrations are normally lower; guideline level may lead to unacceptable deposition of "dust."  Sources—burning of wood, diesel, and other fuels; industrial plants; agriculture (plowing, burning off fields); unpaved roads.  Health effects—nose and throat irritation, lung damage, bronchitis, early death.  Environmental effects—Particulates are the main source of haze that reduces visibility.  Property damage—Ashes, soot, smoke, and dust can dirty and discolor structures and other property, including clothes and furniture.	C-4 [c] C-4 [m]
Radon (Rn)	Soil gas	4 pCi/L <sup>a</sup>	Based on lung cancer, average exposure for one year.	C-7 [c,m] C-10 [m]
Sulfur Dioxide (SO <sub>2</sub> )	Unvented space heaters (kerosene) Outdoor air	80 µg/m <sup>3</sup>	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for one year (WHO: 50 µg/m <sup>3</sup> if with PM).  Source—burning of coal and oil, especially high-sulfur coal from the eastern United States; industrial processes (paper, metals).  Health effects—breathing problems; may cause permanent damage to lungs.  Environmental effects—SO <sub>2</sub> is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can also reduce visibility.  Property damage—Acid aerosols can eat away stone used in buildings, statues, monuments, etc.	C-4 [c] C-4 [m] C-18
Total Volatile Organic Compounds (TVOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	Precise guidance on TVOC concentrations cannot be given	A variety of definitions of TVOC have been employed in the past. Reference C-27 contains a specific definition that reflects recent thinking on the subject.  There is insufficient evidence that TVOC measurements can be used to predict health or comfort effects. In addition, odor and irritation responses to organic compounds are highly variable. Furthermore, no single method currently in use measures all organic compounds that may be of interest. Therefore, some investigators have reported the total of all measured VOCs as the SumVOC in order to make explicit that the reported value does not represent the total of all VOCs present. Some of the references included here use this method for presenting VOC measurement results. Setting target concentrations for TVOCs is not recommended. Setting target concentrations for specific VOCs of concern is preferred.	C-9 [m] C-14, 26-28, 35, 37
Volatile Organic Compounds (VOCs) (See Table C-3 for a list of selected compounds)	New building materials and furnishings Consumable products Maintenance materials Outdoor air Parking garages Refueling stations	Must be determined for each individual compound (See Table C-3 for a list of selected compounds)	Individual volatile organic compounds may be contaminants of concern in the application of the IAQ Procedure. Concentrations of concern range from less than 1 part per billion (ppb) for some very toxic compounds or for compounds having very low odor thresholds up to concentrations several orders of magnitude higher. Not all compounds can be identified, and toxicological data are incomplete for many compounds.	C-22-26, 28, 42, 43, 44 [c] C-9, 10, 21 [m] C-11, 15, 36, 38, 39, 11

a. USEPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

**Conversion Factors**

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

$$\begin{aligned} \text{ppm} \times \text{molecular weight}/24,450 &= \text{mg/L} \\ \text{ppm} \times \text{molecular weight}/0.02445 &= \mu\text{g}/\text{m}^3 \\ \text{ppm} \times \text{molecular weight}/24.45 &= \text{mg}/\text{m}^3 \\ \text{ppm} \times \text{molecular weight} \times 28.3/24,450 &= \text{mg}/\text{ft}^3 \end{aligned}$$

## Guide for Using Table C-3

Table C-3 provides information that may be beneficial for designers who choose to comply with the Indoor Air Quality Procedure of this Standard. The VOCs included in the table were reported in published, peer-reviewed surveys conducted in office buildings and in new and existing residences in North America during the period 1990–2000 C-42,C-43,C-45. Only those VOCs for which exposure guidelines for the general population have been developed by cognizant authorities are listed in Table C-3.

Reference Exposure Levels (RELs) are guidelines for hazardous substances for acute, 8-hour and chronic inhalation exposures developed by California Office of Health Hazard Assessment (OEHHA). Minimal Risk Levels (MRLs) for hazardous substances are guidelines for acute, intermediate and chronic inhalation exposures developed by the Agency for Toxic Substances and Disease Registry (ATSDR). Factors for  $\mu\text{g}/\text{m}^3$  to ppb concentration conversions are shown.

The table does not purport to represent (a) all possible chemicals found in nonindustrial indoor environments and (b) all concentration guidelines, standards, and regulatory limits. Published, peer-reviewed surveys conducted in office buildings and in new and existing residences in North America since 2000 may identify several more compounds, for some of which guidelines may be available from the cognizant authorities described above.

**TABLE C-3 Concentrations of Interest for Selected Volatile Organic Compounds**

Compound	CAS Number	Chemical Class <sup>a</sup>	Conversion Factor: $\mu\text{g}/\text{m}^3$ to ppb <sup>b</sup>	CA OEHHA REL <sup>c-36</sup>			ATSDR MRL <sup>c-46</sup>		
				Acute <sup>c</sup> ( $\mu\text{g}/\text{m}^3$ )	8-h <sup>d</sup> ( $\mu\text{g}/\text{m}^3$ )	Chronic <sup>e</sup> ( $\mu\text{g}/\text{m}^3$ )	Chronic <sup>e</sup> ( $\mu\text{g}/\text{m}^3$ )	Intermediate <sup>g</sup> (ppb)	Chronic <sup>h</sup> (ppb)
Acetaldehyde	75-07-0	Ald	0.554	470	300	140			
Acrolein	107-02-8	Ald	0.436	2.5	0.7	0.35		3	0.4
Acrylonitrile	107-13-1	Misc	0.460			5		100	
Benzene	71-43-2	Arom	0.313	1300		60		9	3
Bromomethane (Methyl bromide)	74-83-9	Halo	0.258					50	5
1,3-Butadiene	106-99-0	Alke	0.452			20			
2-Butanone	78-93-3	Ket	0.339	13,000					
2-Butoxyethanol	111-76-2	Gly	0.207					6000	3000
t-Butyl methyl ether (Methyl-t-butyl ether)	1634-04-4	Ethr	0.277			8000		2000	700
Carbon disulfide	75-15-0	Misc	0.321	6200		800			300
Carbon tetrachloride	56-23-5	Halo	0.159	1900		40		30	30
Chlorobenzene	108-90-7	ClAro	0.217			1000			
Chloroform	67-66-3	Halo	0.205	150		300		100	20
1,4-Dichlorobenzene	106-46-7	ClAro	0.166			800		2000	10

a. Ale = alcohol; Ethr = ether; Gly = glycol ether; Ket = ketone; Ald = aldehyde; Estr = acetates and other esters; Acid = carboxylic acid; Alka = alkane HC; Alke = alkene HC; Cyl = cyclic HC; Terp = terpene HC; Arom = aromatic HC; ClAro = chlorinated aromatic HC; Halo = halogenated aliphatic HC; Misc = miscellaneous category

b. Conversion factors from  $\mu\text{g}/\text{m}^3$  to ppb

c. Exposure averaging time is 1 hour

d. Exposure averaging time is 8 hours and which may be repeated

e. Designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure

f. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles

g. Exposure to a chemical for a duration of 15–364 days, as specified in the toxicological profiles

h. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles

i. See also Tables C-1 and C-2 for additional guidance on formaldehyde.



**TABLE C-3 Concentrations of Interest for Selected Volatile Organic Compounds (Continued)**

Compound	CAS Number	Chemical Class <sup>a</sup>	Conversion Factor: µg/m <sup>3</sup> to ppb <sup>b</sup>	CA OEHHA REL C-36			ATSDR MRL C-46		
				Acute <sup>c</sup> (µg/m <sup>3</sup> )	8-h <sup>d</sup> (µg/m <sup>3</sup> )	Chronic <sup>e</sup> (µg/m <sup>3</sup> )	Acute <sup>f</sup> (ppb)	Intermediate <sup>g</sup> (ppb)	Chronic <sup>h</sup> (ppb)
1,2-Dichloroethane (Ethylene dichloride)	107-06-2	Halo	0.247						600
Dichloromethane (Methylene chloride)	75-09-2	Halo	0.288	14,000		400	600	300	300
1,4-Dioxane	123-91-1	Ethr	0.278	3000		3000	2000	1000	1000
Ethylbenzene	100-41-4	Arom	0.230			2000	10,000	700	300
Ethylene glycol	107-21-1	Gly	0.394			400	788		
Formaldehyde <sup>i</sup>	50-00-0	Ald	0.815	55	9	9	40	30	8
n-Hexane	110-54-3	Alka	0.284			7000	600		
Naphthalene	91-20-3	Arom	0.191			9			0.7
Phenol	108-95-2	Alc	0.260	5800		200			
2-Propanol (Isopropanol)	67-63-0	Alc	0.407	3200		7000			
2-Propanone (Acetone)	67-64-1	Ket	0.421				26,000	13,000	13,000
Styrene	100-42-5	Arom	0.235	21,000		900	2000		200
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene)	127-18-4	Halo	0.147	20,000		35	200		40
Toluene	108-88-3	Arom	0.265	37,000		300	1000		80
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	Halo	0.183	68,000		1000	2000	700	
Trichloroethene (Trichloroethylene)	79-01-6	Halo	0.186			600	2000	100	
Vinyl chloride	75-01-4	Halo	0.391	180,000			500	30	
Xylene isomers	1330-20-7	Arom	0.230	22,000		700	2000	600	50

a. Alc = alcohol; Ethr = ether; Gly = glycol ether; Ket = ketone; Ald = aldehyde; Est = esters; Acid = carboxylic acid; Alka = alkane HC; Alke = alkene HC; Cyl = cyclic HC; Terp = terpene HC; Arom = aromatic HC; ClAro = chlorinated aromatic HC; Halo = halogenated aliphatic HC; Misc = miscellaneous category

b. Conversion factors from µg/m<sup>3</sup> to ppb

c. Exposure averaging time is 1 hour

d. Exposure averaging time is 8 hours and which may be repeated

e. Designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure

f. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles

g. Exposure to a chemical for a duration of 15–364 days, as specified in the toxicological profiles

h. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles

i. See also Tables C-1 and C-2 for additional guidance on formaldehyde.

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## INFORMATIVE APPENDIX D RATIONALE FOR MINIMUM PHYSIOLOGICAL REQUIREMENTS FOR RESPIRATION AIR BASED ON CO<sub>2</sub> CONCENTRATION

Oxygen is necessary for metabolism of food to sustain life. Carbon and hydrogen in foods are oxidized to carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O), which are eliminated by the body as waste products. Foods can be classified as carbohydrates, fats, and proteins, and the ratio of carbon to hydrogen in each is somewhat different. The respiratory quotient (RQ) is the volumetric ratio of CO<sub>2</sub> produced to oxygen consumed. It varies from 0.71 for a diet of 100% fat to 0.8 for a diet of 100% protein and 1.00 for a diet of 100% carbohydrates<sup>D-1</sup>. A value of RQ = 0.83 applies to a normal diet mix of fat, carbohydrate, and protein.

The rate at which oxygen is consumed and CO<sub>2</sub> is generated depends on physical activity. These relationships are shown in Figure D-2 (see Reference D-2). The breathing rate is shown also. A simple mass balance equation gives the outdoor airflow rate needed to maintain the steady-state CO<sub>2</sub> concentration below a given limit.

$$V_o = N/(C_s - C_o) \quad (D-1)$$

where

$V_o$  = outdoor airflow rate per person

$V_e$  = breathing rate

$N$  = CO<sub>2</sub> generation rate per person

$C_e$  = CO<sub>2</sub> concentration in exhaled breath

$C_s$  = CO<sub>2</sub> concentration in the space

$C_o$  = CO<sub>2</sub> concentration in outdoor air

For example, at an activity level of 1.2 met units (1.0 met = 18.4 Btu/h·ft<sup>2</sup>), corresponding to sedentary persons, the CO<sub>2</sub> generation rate is 0.31 L/min. Laboratory and field studies have shown that with sedentary persons about 15 cfm (7.5 L/s) per person of outdoor air will dilute odors from human bioeffluents to levels that will satisfy a substantial majority (about 80%) of unadapted persons (visitors) to a space<sup>D-3,D-4,D-5,D-6,D-7</sup>. If the ventilation rate is to be held to 15 cfm (7.5 L/s) per person, the resulting steady-state CO<sub>2</sub> concentration relative to that in the outdoor air is

$$\begin{aligned} C_s - C_o &= N/V_o \\ &= 0.31/(7.5 \times 60 \text{ s/min}) \\ &= 0.000689 \text{ L of CO}_2 \text{ per L of air} \\ &\approx 700 \text{ ppm} \end{aligned}$$

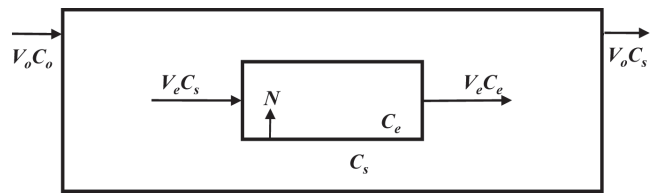


FIGURE D-1 Two-chamber model.

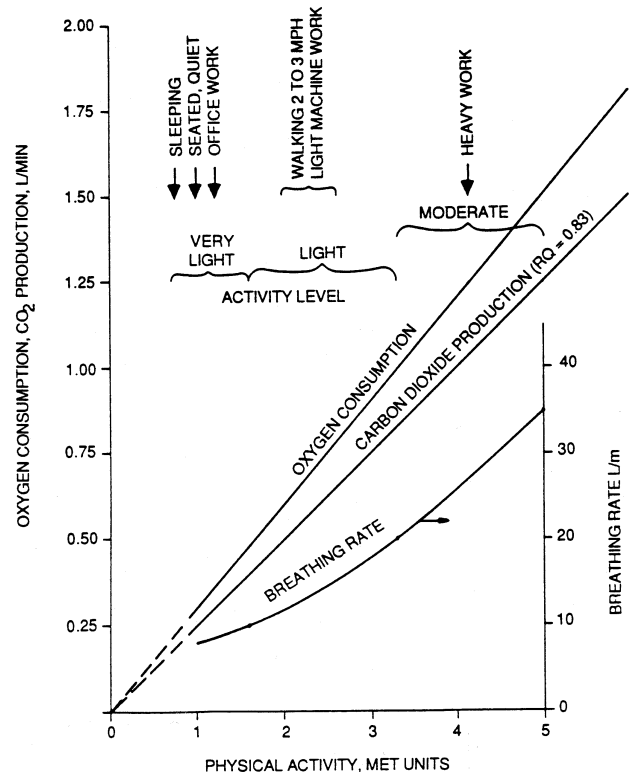


FIGURE D-2 Metabolic data.

Thus, maintaining a steady-state CO<sub>2</sub> concentration in a space no greater than about 700 ppm above outdoor air levels will indicate that a substantial majority of visitors entering a space will be satisfied with respect to human bioeffluents (body odor). A more detailed discussion of this relationship between CO<sub>2</sub> concentrations and the perception of bioeffluents, as well as the use of indoor CO<sub>2</sub> to estimate building ventilation rates, is contained in ASTM Standard D6245<sup>D-8</sup>.

CO<sub>2</sub> concentrations in acceptable outdoor air typically range from 300 to 500 ppm. High CO<sub>2</sub> concentrations in the outdoor air can be an indicator of combustion and/or other contaminant sources.

Figure D-3 shows the outdoor airflow rate required as a function of physical activity and steady-state room concentration. If the activity level is greater than 1.2 met, the required ventilation must be increased to maintain the same CO<sub>2</sub> level.

Also the decrease in oxygen content of the room air can be found from Equation D-1 when oxygen concentration is substituted for carbon dioxide concentration.

$$C_o - C_s = N/V_o \quad (D-2)$$

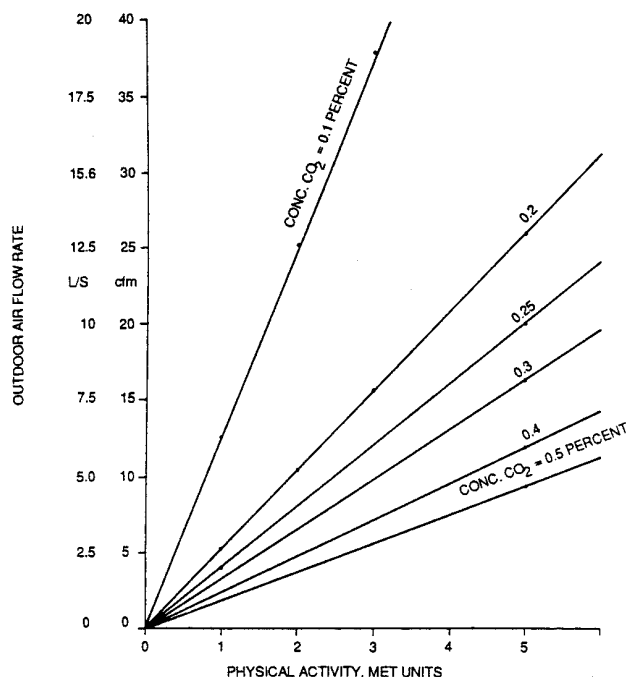


FIGURE D-3 Ventilation requirements.

The term  $N$  now has a negative value with respect to its use in Equation D-1 because oxygen is consumed rather than generated.

$$C_s = C_o - N/V_o \quad (D-3)$$

The oxygen consumption rate is 0.0127 cfm (0.36 L/min) when the activity level is 1.2 met. For ventilation at a rate of 15 cfm (429 L/m) and an activity level of 1.2 met units, the room oxygen level will be reduced from an outdoor concentration of 20.95% to 20.85%, a percent change of 0.48%  $([20.95 - 20.85]/20.95)$ . Unlike oxygen,  $\text{CO}_2$  is generated as a result of activity. At 1.2 met, the  $\text{CO}_2$  indoors is raised from the outdoor background of 0.03% to 0.1%, a percent change

of 230%. Thus, measuring the increase of  $\text{CO}_2$  is clearly more significant than measuring the decrease of oxygen.

## REFERENCES

- D-1. McHattie, L.A. 1960. Graphic visualization of the relations of metabolic fuels: Heat:  $\text{O}_2$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ : Urine N., pp. 677–83. In *J. Applied Physiology* Vol. 15, No. 4.
- D-2. *ASHRAE Handbook—2005 Fundamentals*, Chapter 8. 2005. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA 30329.
- D-3. Berg-Munch, B., G.H. Clausen, and P.O. Fanger. 1986. Ventilation requirements for the control of body odor in spaces occupied by women, pp. 195–200. In *Environ. Int.* Vol. 12.
- D-4. Cain, W.S., et al. 1983. Ventilation requirements in buildings—I. Control of occupancy odor and tobacco smoke odor, pp. 1183–97. In *Atmos. Environ.* Vol. 17, No. 6.
- D-5. Fanger, P.O., and B. Berg-Munch. 1983. Ventilation and body odor, pp. 45–50. In *Proceedings of an Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- D-6. Iwashita, G., K. Kimura, et al. 1989. Pilot study on addition of old units for perceived air pollution sources, pp. 321–24. In *Proceedings of SHASE Annual Meeting*. Tokyo: Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.
- D-7. Yaglou, C.P., E.C. Riley, and D.I. Coggins. 1936. Ventilation requirements, pp. 133–62. In *ASHRAE Transactions* Vol. 42.
- D-8. ASTM. 1998. *ATSM Standard D6245, Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation*. Philadelphia: American Society for Testing and Materials, D6245-98.

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## INFORMATIVE APPENDIX E ACCEPTABLE MASS BALANCE EQUATIONS FOR USE WITH THE IAQ PROCEDURE

When applying the IAQ Procedure from Section 6.3, mass balance analysis may be employed to determine outdoor air ventilation requirements to control indoor contaminant levels.

Table E-1 presents mass balance equations for analysis of single-zone systems. Figures E-1 and E-2 show representative single-zone systems. A filter may be located in the recirculated airstream (location A) or in the supply (mixed) airstream (location B).

Variable-air-volume (VAV) single-zone systems reduce the circulation rate when the thermal load is lower than the design load. This is accounted for by a flow reduction fraction ( $F_r$ ).

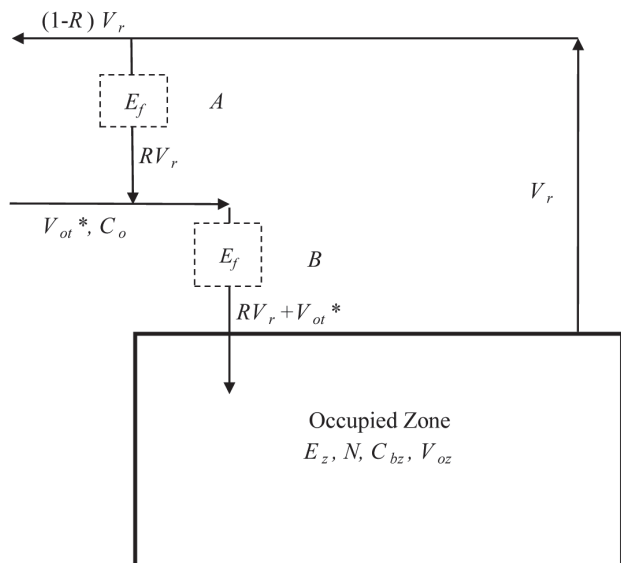
A mass balance equation for the contaminant-of-concern may be written and used to determine the required outdoor airflow or the breathing zone contaminant concentration for the various system arrangements. Six permutations for air-handling and single-zone air distribution systems are described in Table E-1. The mass balance equations for computing the required outdoor airflow and the breathing-zone

**TABLE E-1 Required Zone Outdoor Airflow or Space Breathing Zone Contaminant Concentration with Recirculation and Filtration for Single-Zone Systems**

Required Recirculation Rate				
Filter Location	Flow	Outdoor Airflow	Required Zone Outdoor Airflow ( $V_{oz}$ in Section 6)	Space Breathing Zone Contaminant Concentration
None	VAV	100%	$V_{oz} = \frac{N}{E_z F_r (C_{bz} - C_o)}$	$C_{bz} = C_o + \frac{N}{E_z F_r V_{oz}}$
A	Constant	Constant	$V_{oz} = \frac{N - E_z R V_r E_f C_{bz}}{E_z (C_{bz} - C_o)}$	$C_{bz} = \frac{N + E_z V_{oz} C_o}{E_z (V_{oz} + R V_r E_f)}$
A	VAV	Constant	$V_{oz} = \frac{N - E_z F_r R V_r E_f C_{bz}}{E_z (C_{bz} - C_o)}$	$C_{bz} = \frac{N + E_z V_{oz} C_o}{E_z (V_{oz} + F_r R V_r E_f)}$
B	Constant	Constant	$V_{oz} = \frac{N - E_z R V_r E_f C_{bz}}{E_z [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z V_{oz} (1 - E_f) C_o}{E_z (V_{oz} + R V_r E_f)}$
B	VAV	100%	$V_{oz} = \frac{N}{E_z F_r [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z F_r V_{oz} (1 - E_f) C_o}{E_z F_r V_{oz}}$
B	VAV	Constant	$V_{oz} = \frac{N - E_z F_r R V_r E_f C_{bz}}{E_z [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z V_{oz} (1 - E_f) C_o}{E_z (V_{oz} + F_r R V_r E_f)}$

Symbol or Subscript	Definition
$A, B$	filter location
$V$	volumetric flow
$C$	contaminant concentration
$E_z$	zone air distribution effectiveness
$E_f$	filter efficiency
$F_r$	design flow reduction fraction factor
$N$	contaminant generation rate
$R$	recirculation flow factor
Subscript: $o$	outdoor
Subscript: $r$	return
Subscript: $b$	breathing
Subscript: $z$	zone

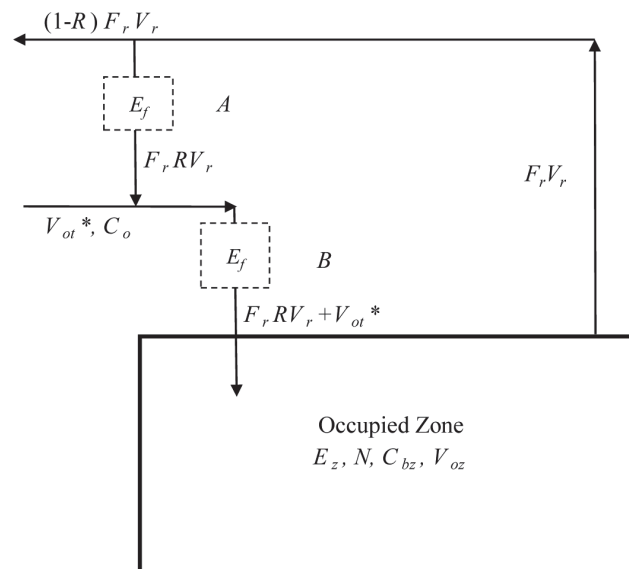


**FIGURE E-1 Ventilation system schematic—constant volume system with no infiltration/exfiltration. (\* $V_{ot} = V_{oz}$  for single-zone systems.**

contaminant concentration at steady-state conditions for each single-zone system are presented in Table E-1.

If the allowable breathing zone contaminate concentration is specified, the equations in Table E-1 may be solved for the zone outdoor airflow rate ( $V_{oz}$ ). When the zone outdoor airflow rate is specified, the equations may be solved for the resulting breathing zone contaminant concentration.

While the calculation methods in this appendix are based on single-zone systems and steady-state analysis, calculation



**FIGURE E-2 Ventilation system schematic—variable air volume system with no infiltration/exfiltration. (\* $V_{ot} = V_{oz}$  for single-zone systems.**

methods that account for multiple-zone and transient effects are also available <sup>E-1</sup>.

## REFERENCE

- E-1. Dols, W.S., and G.N. Walton. 2002. CONTAMW 2.0 User Manual. National Institute of Standards and Technology, NISTIR 6921.

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INFORMATIVE APPENDIX F  
INFORMATION ON SELECTED NATIONAL STANDARDS AND  
GUIDELINES FOR PM10, PM2.5, AND OZONE

TABLE F-1 Information Sources for Identifying Noncomplying Locations  
(Information Current as of October 1, 2015)

Country	PM10	PM2.5	Ozone
United States	Find nonattainment areas at: <a href="http://www3.epa.gov/airquality/greenbook/index.html">http://www3.epa.gov/airquality/greenbook/index.html</a>	Find nonattainment areas at: <a href="http://www3.epa.gov/airquality/greenbook/index.html">http://www3.epa.gov/airquality/greenbook/index.html</a>	<b>ASHRAE 62.1-2016 air-cleaning requirement:</b> See Figure F-1 for a list of U.S. locations exceeding the 0.107 level as of 10/1/15
Canada	National Building Code of Canada 2010—Part 6, HVAC <a href="http://www.nationalcodes.ca">www.nationalcodes.ca</a>	National Building Code of Canada 2010—Part 6, HVAC <a href="http://www.nationalcodes.ca">www.nationalcodes.ca</a>	National Building Code of Canada 2010—Part 6, HVAC <a href="http://www.nationalcodes.ca">www.nationalcodes.ca</a>

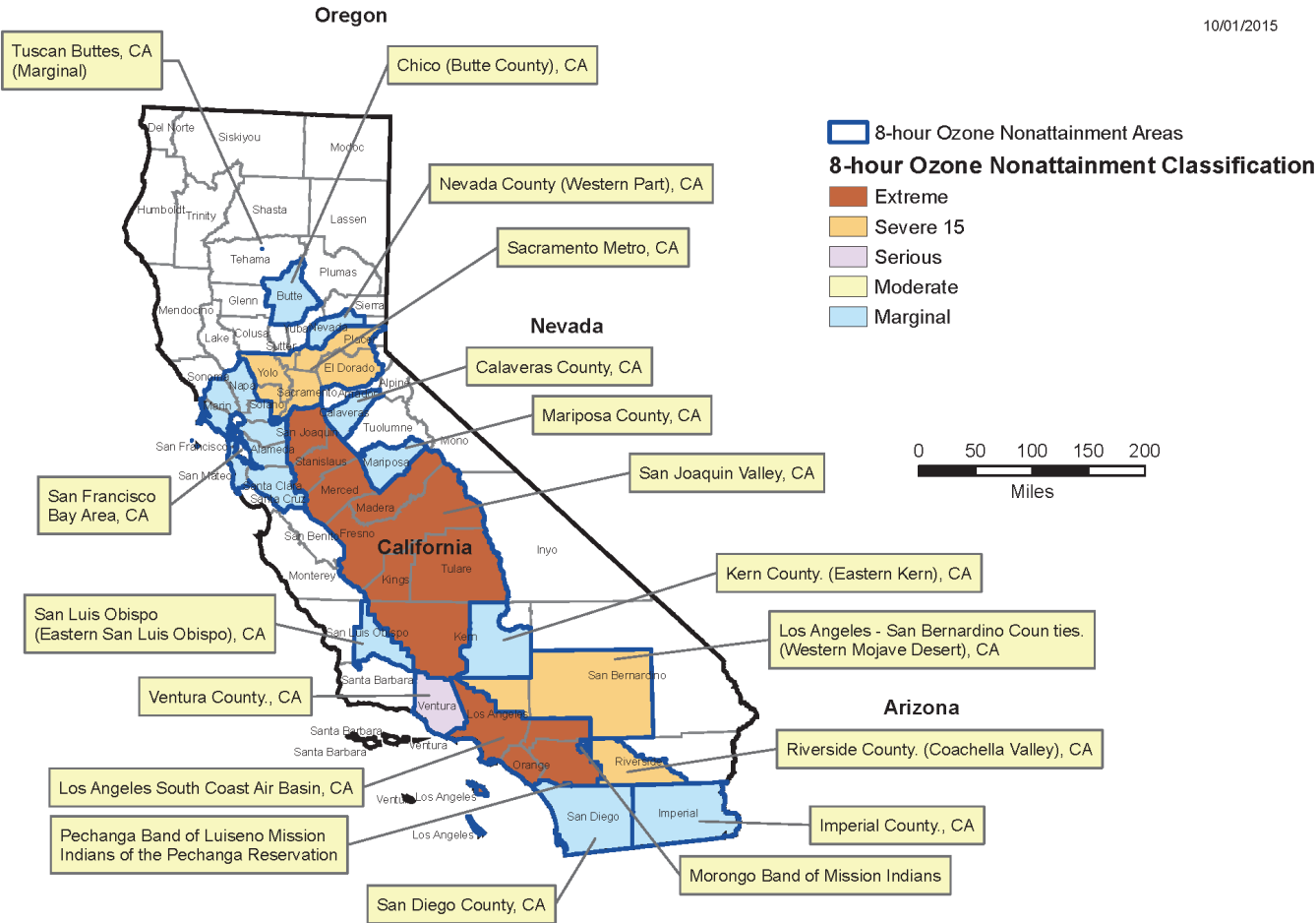


FIGURE F-1 California 8-hour ozone nonattainment areas. (Source: USEPA)

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## INFORMATIVE APPENDIX G APPLICATION AND COMPLIANCE

This appendix contains application and compliance suggestions that are intended to assist users and enforcement agencies in applying this standard.

For the most part, ANSI/ASHRAE Standard 62.1-2016 is specifically written for new buildings because some of its requirements assume that other requirements within the standard have been met. In the case of existing buildings, retroactive application and compliance with all the requirements of this standard may not be practical. However, the principles established in this standard may be applied to most existing commercial and institutional buildings. Some existing buildings may achieve acceptable IAQ despite not meeting the requirements of Standard 62.1-2016 due to, for example, good maintenance and capital improvement procedures, building materials that, by virtue of their age, have very low contaminant emission rates, and many other factors.

### G1. APPLICATION

**G1.1 New Buildings.** All sections and normative appendices should apply to new buildings falling within the scope of this standard.

**G1.2 Existing Buildings.** The standard should be applied to existing buildings at least in the circumstances described in the following subsections.

**G1.2.1 Additions to Existing Buildings.** All additions to existing buildings should meet the requirements of this standard as if the addition were a new building. An exception may be made when an existing ventilation system is extended to serve the addition. In this case, the existing system components, such as fans and cooling and heating equipment, need not meet the requirements of this standard. However, the extended existing system should remain in compliance with ventilation codes and standards that were in effect at the time it was permitted for construction.

**G1.2.2 Repairs.** Repairing (making operational) existing equipment or other building components does not require the building or any of its components to retroactively comply with this standard.

**G1.2.3 Replacement.** Any component of a building that is removed and replaced should meet the applicable requirements of Section 5, “Systems and Equipment,” of this standard for that component. An exception may be made in cases when replacing a component of like size and kind, provided all requirements of codes and standards used at the time of original system design and installation are met. For example, replacement of an air-conditioning unit with one of similar capacity would not require retroactive compliance with venti-

lation rates and other requirements of this standard. Unaltered components do not need to be retroactively brought into compliance except when there are substantial alterations (as defined below).

**G1.2.4 Substantial Alterations.** If a building is substantially altered, the requirements of this standard should be met as if the building were new. A building would be considered substantially altered if the cost of the revisions exceeds 50% of the building’s fair market value, excluding the cost of compliance with this standard.

**G1.2.5 Change in Use.** If the space application category as listed in Table 6.2.2.1 changes, such as from office to retail, the minimum ventilation rates required by Section 6, “Procedures,” should be met for that space.

### G2. COMPLIANCE

Demonstrating that acceptable IAQ has been achieved, such as by measuring contaminant concentrations or surveying occupants, would not be required by this standard except where required by the IAQ Procedure.

---

The following section provides suggested model code language.

## APPLICATION AND COMPLIANCE

### Application

*New Buildings.* All sections and normative appendices apply to new buildings falling within the scope of this standard.

### Existing Buildings

*Additions to Existing Buildings.* All additions to existing buildings within the scope of this standard shall meet the requirements of all sections and normative appendices.

**Exception:** When an existing ventilation system is extended to serve an addition, the existing system components, such as fans and cooling and heating equipment, need not meet the requirements of this standard. However, the extended existing system must remain in compliance with ventilation codes and standards that were in effect at the time it was permitted for construction.

**Repairs.** Repairing (making operational) existing equipment or other building components shall be allowed without requiring the building or any of its components to comply with this standard.

**Replacement.** Any component of a building that is removed and replaced shall meet the applicable requirements of Section 5, “Systems and Equipment,” of this standard for that component. Unaltered components are not required to be brought into compliance except as required due to a change in use.

**Exception:** Replacement of a building component or individual piece of equipment with a component of like size and kind, provided that all requirements of codes effective at the time of original system design and installation are met. For example, replacement of an air-conditioning

*unit with one of similar capacity would not require that the ventilation rate requirements and other requirements of this standard be met.*

**Substantial Alterations.** *If a building is substantially altered, all sections and normative appendices of this standard shall be met as if the building were new. A building shall be considered substantially altered if the cost of the revisions exceeds 50% of the building's fair market value, excluding the cost of compliance with all sections and normative appendices of this standard.*

**Change in Use.** *If the space application category as listed in Table 2 changes, such as from office to retail, the minimum ventilation rates required by Section 6, "Procedures," shall be met for that space.*

### **Compliance**

*Demonstrating that acceptable IAQ has been achieved, such as by measuring contaminant concentrations or surveying occupants, is not required by this standard except where required by the IAQ Procedure.*



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**INFORMATIVE APPENDIX H  
DOCUMENTATION**

This appendix summarizes the requirements for documentation contained in the body of the standard using a series of templates that summarizes the design criteria used and assumptions made to comply with this standard. One way to comply with the documentation requirements of the standard is to complete these templates as appropriate during the project design process.

**H1. OUTDOOR AIR QUALITY**

Section 4.3 of this standard requires an investigation of the outdoor air quality in the vicinity of the project site. This template offers a means of documenting the results of both the regional and local investigations and the conclusions reached

concerning the acceptability of the outdoor air quality for indoor ventilation.

**H2. BUILDING VENTILATION DESIGN CRITERIA**

This template provides a means of documenting significant design criteria for the overall building. Only the last column, in accordance with Section 5.1.3, is specifically required by the standard. The other columns are motivated by the general documentation requirement described in Section 6.6.

**H3. VENTILATION RATE PROCEDURE**

Section 6.2 permits the use of this prescription-based procedure to design ventilation systems. This template documents the assumptions made when using this procedure as required by Sections 5.16.4 and 6.6.

**H4. IAQ PROCEDURE**

Section 6.3 permits the use of this performance-based procedure to design ventilation systems. This template documents the design criteria and assumptions made when using this procedure and justification of the design approach, as required by Section 6.3.2.

Regional Outdoor Air Quality Pollutants	Attainment or Nonattainment According to the U.S. Environmental Protection Agency	
Particulates (PM2.5)	(Yes/No)	
Particulates (PM10)	(Yes/No)	
Carbon monoxide—1 hour/8 hours	(Yes/No)	
Ozone	(Yes/No)	
Nitrogen dioxide	(Yes/No)	
Lead	(Yes/No)	
Sulfur Dioxide	(Yes/No)	
Local Outdoor Air Quality Survey	Date:	Time:
(a) Area surveyed	(Brief description of the site)	
(b) Nearby facilities	(Brief description type of facilities—industrial, commercial, hospitality, etc.)	
(c) Odors or irritants	(List and describe)	
(d) Visible plumes	(List and describe)	
(e) Nearby sources of vehicle exhaust	(List and describe)	
(f) Prevailing winds	(Direction)	
(g) Other observations		
(Conclusions	(Remarks concerning the acceptability of the outdoor air quality)	

## Building Ventilation Design Criteria

Total Building Outdoor Air Intake	Total Building Exhaust Air (see Section 5.9.2)	Outdoor Air Cleaning Required (See Section 6.2.1)		Occupied Space Relative Humidity (Choose One Criterion per Section 5.9.1)		Air Balancing (See Section 5.1.3)
		Particulate Matter	Ozone	Peak Outdoor DP at Peak Indoor Latent Load	Lowest Space SHR at Concurrent Outdoor Condition	
(cfm)	(cfm)	(Yes/No)	(Yes/No)	(% RH based on equipment selection)	(% RH based on equipment selection)	(NEBB, AABC, etc.)

Space Identification	Space Type	Occupant Density	Rate/Person	Rate/SF	Zone Air Distribution Effectiveness	System Ventilation Efficiency	Class of Air
(List number or name of each ventilation zone, such as office number or name, retail space name, classroom number)	(List occupancy category of the space from Table 6.2.2.1 such as office space, retail sales, classroom age 5–8, etc.)	(People/ft <sup>2</sup> or m <sup>2</sup> )	(cfm or L/s)	(cfm or L/s)	(Table 6.2.2.2)	(Table 6.2.5.2 or Normative Appendix A)	(Tables 5.16.1 or 6.2.21; include justification for classification if not in these tables)

## IAQ Procedure Assumptions

Contaminant of Concern	Contaminant Source	Contaminant Strength	Contaminant Target Concentration			Perceived IAQ	Design Approach
			Limit	Exposure Period	Cognizant Authority Reference		
(Identify and list)	(Identify and list)	(Determine and list)	(List)	(List)	(List)	(Percentage of satisfied building occupants)	(Select from Section 6.3.4 and include justification)

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## INFORMATIVE APPENDIX I

### NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

For locations within the United States, the following table shows the ambient air quality standards that determine the regional air quality status of “attainment” or “nonattainment” for the building location.

**TABLE I-1 National Ambient Air Quality Standards (NAAQS) <sup>I-1</sup>**

Pollutant	Primary Stds.	Averaging Times	Secondary Stds.
Carbon monoxide	9 ppm (10 mg/m <sup>3</sup> )	8-hour <sup>a</sup>	None
	35 ppm (40 mg/m <sup>3</sup> )	1-hour <sup>a</sup>	None
Lead	0.15 µg/m <sup>3</sup>	Rolling three-month average	Same as primary
Nitrogen dioxide	100 ppb	1-hour <sup>b</sup>	—
	0.053 ppm (100 µg/m <sup>3</sup> )	Annual (arithmetic mean)	Same as primary
Particulate matter (PM <sub>10</sub> )	150 µg/m <sup>3</sup>	24-hour <sup>c</sup>	Same as primary
Particulate matter (PM <sub>2.5</sub> )	12 µg/m <sup>3</sup>	Annual <sup>d</sup> (arithmetic mean)	15 µg/m <sup>3</sup>
	35 µg/m <sup>3</sup>	24-hour <sup>b</sup>	Same as primary
Ozone	0.075 ppm	8-hour <sup>e</sup>	Same as primary
Sulfur dioxide	75 ppb	1-hour <sup>f</sup>	—
	—	3-hour <sup>(1)</sup>	0.5 ppm

a. Not to be exceeded more than once per year.

b. 98th percentile, averaged over 3 years

c. Not to be exceeded more than once per year on average over 3 years.

d. Average over three years.

e. 3-year average of the fourth-highest daily maximum 8-hour average ozone concentration.

f. 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.

## REFERENCES

- I-1. *National Primary and Secondary Ambient Air Quality Standards, Code of Federal Regulations, Title 40 Part 50 (40 CFR 50)*, as amended July 30, 2004 and Oct. 17, 2006. U.S. Environmental Protection Agency. [www.epa.gov/air/criteria.html](http://www.epa.gov/air/criteria.html), accessed January 30, 2013.

(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 ANSI 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 or ANSI.)

## INFORMATIVE APPENDIX J

### INFORMATIVE REFERENCES

- J1. *Industrial Ventilation: A Manual of Recommended Practice*, 28th Edition, 2012. American Conference of Governmental Industrial Hygienists (ACGIH), Committee on Industrial Ventilation, Lansing, MI.
- J2. *2015 ASHRAE Handbook—HVAC Applications*. Atlanta: ASHRAE.
- J3. *2013 ASHRAE Laboratory Design Guide*. Atlanta: ASHRAE.
- J4. *NSF/ANSI 49-2012, Biological Safety Cabinetry: Design, Construction, Performance and Field Certification*. Ann Arbor, MI: National Sanitation Foundation International.
- J5. *AMCA 511-13, Certified Ratings Program—Product Rating Manual for Air Control Devices*. Arlington Heights, IL: Air Movement and Control Association International, Inc.
- J6. *AMCA 500-L-12, Laboratory Methods of Testing Louvers for Rating*. Arlington Heights, IL: Air Movement and Control Association International, Inc.

(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 ANSI 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 or ANSI.)

## INFORMATIVE APPENDIX K

### ADDENDA DESCRIPTION INFORMATION

ANSI/ASHRAE Standard 62.1-2016 incorporates ANSI/ASHRAE Standard 62.1-2013 and Addenda a, c, d, e, f, g, h, i, j, k, p, q, r, and s to ANSI/ASHRAE Standard 62.1-2013. Table K-1 lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE and ANSI approval dates for each addendum.

**TABLE K-1 Addenda to ANSI/ASHRAE Standard 62.1-2013**

Addendum	Section(s) Affected	Description of Changes*	Approval Dates:
			• Standards Committee • ASHRAE BOD • ANSI
a	2 Scope; 3 Definitions	Currently, ASHRAE Standard 62.1 has responsibility for multifamily residential buildings that are 4 stories or more, and ASHRAE Standard 62.2 has responsibility for residential buildings 3 stories and less. The ventilation rates for dwelling units in Standard 62.1 are different from the rates in Standard 62.2 and this inconsistency has caused concern for some. Additionally, Standard 62.1 does not address modest retrofits whereas Standard 62.2 does. The retrofit market is a major user of ASHRAE ventilation standards. This addendum is a scope change which will do away with the building height threshold, bringing the dwelling units themselves into Standard 62.2 regardless of height while common areas would be covered by Standard 62.1. The change will allow for consistency across dwelling units and also allow application of ASHRAE ventilation standards to the multifamily retrofit market.	September 16, 2014 October 3, 2014 October 29, 2014
c	3 Definitions	Standard 62.1 contains requirements for ventilation of spaces which are free of environmental tobacco smoke (ETS-free). It also contains requirements for separation of an ETS-free area from any spaces containing environmental tobacco smoke.  Since the current language relating to ETS was added to the standard, electronic smoking devices (commonly called e-cigarettes) have come on the market and are increasingly popular. Also, some jurisdictions have legalized the smoking of cannabis.  This addendum revises the current definition of ETS to include emissions from electronic smoking devices and from smoking of cannabis. The existing requirements for separation of ETS-free spaces from ETS spaces remain unchanged.  This addendum clarifies the intent of the standard that provision of acceptable indoor air quality is incompatible with the presence of ETS, including cannabis smoke and e-cigarette emissions. The ventilation rates determined in accordance with the provisions of the standard apply only to spaces where these emissions are not present and which are adequately separated from spaces where they are present.	January 28, 2015 January 28, 2015 (Technology Council) January 29, 2015
d	5.8 Particulate Matter Removal	This addendum adds an exception to Section 5.8 (Particulate Matter Removal). In sensible-only cooling (e.g. sensible-only chilled beams) the equipment's purpose is to provide only sensible cooling. In this case the coil surface would never be wet and the filtration requirements intended for wetted surfaces should not apply. Latent cooling for these systems would be provided by other portions of the system, such as cooling coils in the primary air stream, which would then have independent upstream air filtration.	June 27, 2015 July 1, 2015 (Technology Council) July 2, 2015
e	8.1.2 Application; 8.2 Operations and Maintenance Manual; 8.4 Ventilation System Maintenance; New Table 8.4.1 Minimum Maintenance Activity and Frequency for Ventilation System Equipment and Associated Components	This addendum modifies Section 8, Operation and Maintenance, incorporating calibration requirements for airflow monitoring sensors and systems. The requirements in Table 8.4.1 (Minimum Maintenance Activity and Frequency) were initially based on requirements in ASHRAE/ACCA Standard 180-2012, Standard Practice for Inspection and Maintenance of Commercial-Building HVAC Systems, although the SSPC has modified some of those requirements.	January 23, 2016 January 27, 2016 February 24, 2016

\* These descriptions may not be complete and are provided for information only.

**TABLE K-1 Addenda to ANSI/ASHRAE Standard 62.1-2013**

Addendum	Section(s) Affected	Description of Changes*	Approval Dates: • Standards Committee • ASHRAE BOD • ANSI
f	Table 5.5.1 Air Intake Minimum Separation Distance; Section 5.5.2 Rain Entrainment; 9. References; F1.1 Application; New Informative Appendix J—Informative Bibliography	In preparation for publication of Standard 62.1-2016, this addendum updates the normative references included in the Standard. This process includes reviewing the references to ensure that their content has not been changed such that they should no longer be referenced and that they are written in normative language. References that are not in normative language are being moved to a new Informative Bibliography. In some cases, the language of the Standard where these documents are referenced needs to be modified. In particular, changes to the notes to Table 5.5.1 are made to avoid referencing non-normative documents and to improve the normative language used.	January 23, 2016 January 27, 2016 (Technology Council) January 28, 2016
g	5.11.2 Finned-Tube Coil Selection for Cleaning	This addendum is from a change proposal submitted from outside the SSPC. The proposer pointed out that the addendum provided an exception which essentially allows coils which are very difficult to clean as long as “instructions for . . . cleaning” are provided. The SSPC agrees that providing instructions does not make cleaning these coils any more feasible, and therefore the exception should be deleted.	January 23, 2016 January 27, 2016 (Technology Council) January 28, 2016
h	3. Definitions; 4.2 Local Air Quality; 4.3 Documentation; 5.4.1 Resistance to Mold Growth; 5.5.2 Rain Entrainment; 5.5.4 Snow Entrainment; 5.7 Combustion Air; 5.9.2 Building Exfiltration; 5.10.2 Drain Outlet; 5.10.4 Pan Size; 5.13.1 Equipment Clearance; 5.14.2 Condensation on Interior Surfaces; 5.16.1 Classification; 5.16.2.1 Air Cleaning; 5.16.2.3 Ancillary Spaces; 5.17.7 Signage; 5.17.8 Reclassification; 6.1 General; 6.1.3 Natural Ventilation; 6.2.1 Outdoor Air Treatment; Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone; 6.2.2.3 Zone Outdoor Airflow; 6.2.5.1 Primary Outdoor Air Fraction; 6.2.5.3.2 Design System Population; 6.2.6.1 Variable Load Conditions; 6.3.1 Contaminant Sources; 6.3.4 Design Approach; 6.3.5 Combined IAQ Procedures and Ventilation Rate Procedure; 6.4.1.3 Corner Openings; 6.4.3 Control and Accessibility; 6.6 Design Documentation Procedures; 7.2.3 Testing of Drain Pans; 8.4.1.3 Humidifiers; 8.4.1.4 Dehumidification Coils; Table 8.4.1 Minimum Maintenance Activity and Frequency; 8.4.1.8 Outdoor Airflow Verification; 9. References; Normative Appendix A—Multiple-Zone Systems	The changes to the standard in this addendum are for the purpose of complying with ASHRAE’s mandatory language policy for standards. The changes are intended to clarify the requirements and reduce ambiguity in interpretation and enforcement. Many of these changes will change requirements of the standard.	January 23, 2016 January 27, 2016 February 24, 2016
i	3. Definitions; 5.5 Outdoor Air Intakes; Normative Appendix B—Separation of Exhaust Outlets and Outdoor Air Intakes	This addendum changes Appendix F (Separation of Exhaust Outlets and Outdoor Air Intakes) from informative to normative. This addendum is for the purpose of making language in the standard mandatory in compliance with current ASHRAE requirements. <b>The 2016 edition of Standard 62.1 renames Normative Appendix F as Normative Appendix B. Subsequent appendices are renamed accordingly.</b>	January 23, 2016 January 27, 2016 February 24, 2016

\* These descriptions may not be complete and are provided for information only.

**TABLE K-1 Addenda to ANSI/ASHRAE Standard 62.1-2013**

Addendum	Section(s) Affected	Description of Changes*	Approval Dates:
			• Standards Committee • ASHRAE BOD • ANSI
j	3 Definitions; 6.3 Indoor Air Quality (IAQ) Procedure	<p>This addendum adds requirements to the Indoor Air Quality Procedure (IAQP) for determining minimum ventilation rates by including consideration of the combined effects of multiple contaminants of concern on individual organ systems. This “additive” effect is already implicit in the Ventilation Rate Procedure. This change is intended to improve the IAQP by requiring consideration of these additive effects that are well established in the literature for many organ systems.</p> <p>The change requires identifying those contaminants of concern which act on individual organs and identifying those contaminants as a “contaminant mixture of concern.” A new calculation is provided for determining whether a particular ventilation rate maintains the concentration of the mixture within acceptable limits.</p> <p>The addendum does not require that the list of contaminants of concern for a particular application be any different than it would be without the change, nor will the individual concentration limits for those contaminants be any different. The only change is to consider a combined concentration for the mixture rather than to consider each contaminant individually.</p>	September 26, 2013 November 8, 2013 December 5, 2013
k	Table 5.16.1 Airstreams	This addendum modifies the standard such that laboratory exhaust is assigned a default of Air Class 4, but explicitly allows a responsible EH&S professional to determine that a lower air class is appropriate for particular systems. If they assign a lower air class, then the use of heat wheel energy recovery would be allowed. The SSPC believes that determination of the appropriate air class is best made by a qualified professional on a case by case basis.	June 28, 2014 July 2, 2014 July 3, 2014
p	3 Definitions; 6.2.7.1.1; 6.2.7.1.2; Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone	At present, all occupancy types are required to provide no less than the area component of the minimum ventilation rate during periods when the space is “expected to be occupied.” A previous interpretation clarified that this prohibited the use of occupancy sensors to reduce the ventilation rate to zero during these times. This addendum allows the ventilation to be reduced to zero through the use of occupancy sensors (not through contaminant or CO <sub>2</sub> measurements) for spaces of selected occupancy types. These occupancy types are identified by a new Note H to Table 6.2.2.1 (Minimum Ventilation Rates in Breathing Zone). The occupancy types where this is allowed are most of those with an Area Outdoor Air Rate of 0.06 cfm/ft <sup>2</sup> .	June 27, 2015 July 1, 2015 (Technology Council) July 2, 2015
q	5.2 Exhaust Duct Location; Table 5.16.1 Airstreams	This addendum modifies Section 5.2 (Exhaust Duct Location) to clarify requirements by including air classes instead of descriptive language, and modifies the requirements by allowing positively pressurized exhaust ducts inside the space of origin.	January 28, 2015 January 28, 2015 (Technology Council) January 29, 2015
r	5.9.2 Exfiltration; 6.2.7.1.1; 6.2.7.1.2; 6.2.7.1.3	<p>This addendum deletes Sections 6.2.7.1.2 and 6.2.7.1.3, relating to demand control ventilation (DVC), and removes an informative note to Section 6.2.7.1.1. The deleted sections remove language which was potentially confusing, retaining the essential requirement for DCV as stated in Section 6.2.7.1.1. The changes remove the assumption that the Standard is intended for use only as calculations for code review and not physical operation.</p> <p>Changes to Section 5.9.2 (Exfiltration) clarify the requirements and extend them to apply under conditions of DCV control operation.</p>	September 16, 2014 October 3, 2014 October 6, 2014
s	Table 6.5 Minimum Exhaust Rates	This addendum modifies Table 6.5 (Minimum Exhaust Rates) to clarify confusing language related to locker and dressing rooms.	January 18, 2014 January 22, 2014 January 23, 2014

\* These descriptions may not be complete and are provided for information only.

#### NOTE

**Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE Web site at [www.ashrae.org/technology](http://www.ashrae.org/technology).**



## **NOTICE**

### **INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS STANDARD UNDER CONTINUOUS MAINTENANCE**

This standard is maintained under continuous maintenance procedures by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. SSPC consideration will be given to proposed changes within 13 months of receipt by the Senior Manager of Standards (SMOS).

Proposed changes must be submitted to the SMOS in the latest published format available from the SMOS. However, the SMOS may accept proposed changes in an earlier published format if the SMOS concludes that the differences are immaterial to the proposed change submittal. If the SMOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

### **ELECTRONIC PREPARATION/SUBMISSION OF FORM FOR PROPOSING CHANGES**

An electronic version of each change, which must comply with the instructions in the Notice and the Form, is the preferred form of submittal to ASHRAE Headquarters at the address shown below. The electronic format facilitates both paper-based and computer-based processing. Submittal in paper form is acceptable. The following instructions apply to change proposals submitted in electronic form.

Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, "prop01.doc," "prop02.doc," etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

For files submitted attached to an e-mail, ASHRAE will accept an electronic signature (as a picture; \*.tif, or \*.wpg) on the change submittal form as equivalent to the signature required on the change submittal form to convey non-exclusive copyright.

**Submit an e-mail containing the change proposal files to:**  
change.proposal@ashrae.org

**Alternatively, mail paper versions to:**  
ASHRAE  
Senior Manager of Standards  
1791 Tullie Circle, NE  
Atlanta, GA 30329-2305

**Or fax them to:**  
Attn: Senior Manager of Standards  
678-539-2129

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE's Home Page, [www.ashrae.org](http://www.ashrae.org), or by contacting a Standards Secretary via phone (404-636-8400), fax (678-539-2129), e-mail ([standards.section@ashrae.org](mailto:standards.section@ashrae.org)), or mail (1791 Tullie Circle, NE, Atlanta, GA 30329-2305).



## FORM FOR SUBMITTAL OF PROPOSED CHANGE TO AN ASHRAE STANDARD UNDER CONTINUOUS MAINTENANCE

**NOTE:** Use a separate form for each comment. Submittals (Microsoft Word preferred) may be attached to e-mail (preferred), or submitted in paper by mail or fax to ASHRAE, Senior Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: [change.proposal@ashrae.org](mailto:change.proposal@ashrae.org). Fax: +1-678-539-2129.

### 1. Submitter:

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I hereby grant ASHRAE the non-exclusive royalty rights, including non-exclusive rights in copyright, in my proposals. I understand that I acquire no rights in publication of the standard in which my proposals in this or other analogous form is used. I hereby attest that I have the authority and am empowered to grant this copyright release.

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***All electronic submittals must have the following statement completed:***

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### 2. Number and year of standard:

### 3. Page number and clause (section), subclause, or paragraph number:

4. I propose to: ☐ Change to read as follows ☐ Delete and substitute as follows  
(check one) ☐ Add new text as follows ☐ Delete without substitution

Use underscores to show material to be added (added) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

### 5. Proposed change:

### 6. Reason and substantiation:

7. Will the proposed change increase the cost of engineering or construction? If yes, provide a brief explanation as to why the increase is justified.

☐ Check if additional pages are attached. Number of additional pages: \_\_\_\_\_

☐ Check if attachments or referenced materials cited in this proposal accompany this proposed change. Please verify that all attachments and references are relevant, current, and clearly labeled to avoid processing and review delays. *Please list your attachments here:*

## **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.

### **About ASHRAE**

ASHRAE, founded in 1894, is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, Standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today.

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