

## Section 403 Mechanical Ventilation

### 403.1 Ventilation System

Mechanical ventilation shall be provided by a method of supply air and return or exhaust air. The amount of supply air shall be approximately equal to the amount of return and exhaust air. The system shall not be prohibited from producing negative or positive pressure. The system to convey ventilation air shall be designed and installed in accordance with Chapter 6.

### 403.2 Outdoor Air Required

The minimum outdoor airflow rate shall be determined in accordance with Section 403.3. Ventilation supply systems shall be designed to deliver the required rate of outdoor airflow to the breathing zone within each occupiable space.

**Exception:** Where a registered design professional demonstrates that an engineered ventilation system design will prevent the maximum concentration of contaminants from exceeding that obtainable by the rate of outdoor air ventilation determined in accordance with Section 403.3, the minimum required rate of outdoor air shall be reduced in accordance with such engineered system design.

#### 403.2.1 Recirculation of Air

The outdoor air required by Section 403.3 shall not be recirculated. Air in excess of that required by Section 403.3 shall not be prohibited from being recirculated as a component of supply air to building spaces, except that:

1. Ventilation air shall not be recirculated from one dwelling unit to another or to dissimilar occupancies.
2. Supply air to a swimming pool and associated deck areas shall not be recirculated unless such air is dehumidified to maintain the relative humidity of the area at 60 percent or less. Air from this area shall not be recirculated to other uses or occupancies.
3. Where mechanical exhaust is required by Note b of Table 403.3, recirculation of air from such spaces shall be prohibited. All air supplied to such spaces shall be exhausted, including any air in excess of that required by Table 403.3.
4. Where mechanical exhaust is required by Note g of Table 403.3, mechanical exhaust is required and recirculation is prohibited.

#### 403.2.2 Transfer Air

Except where recirculation from such spaces is prohibited by Table 403.3, air transferred from occupiable spaces is not prohibited from serving as makeup air for required exhaust systems in such spaces as kitchens, baths, toilet rooms, elevators and smoking lounges. The amount of transfer air and exhaust air shall be sufficient to provide the flow rates as specified in Section 403.3. The required outdoor airflow rates specified in Table 403.3 shall be introduced directly into such spaces or into the occupied spaces from which air is transferred or a combination of both.

### 403.3 Outdoor Airflow Rate

Ventilation systems shall be designed to have the capacity to supply the minimum outdoor airflow rate determined in accordance with this section. The occupant load utilized for design of the ventilation system shall not be less than the number determined from the estimated maximum occupant load rate indicated in Table 403.3. Ventilation rates for occupancies not represented in Table 403.3 shall be those for a listed occupancy classification that is most similar in terms of occupant density, activities and building construction; or shall be determined by an approved engineering analysis. The ventilation system shall be designed to supply the required rate of ventilation air continuously during the period the building is occupied, except as otherwise stated in other provisions of the code.

With the exception of smoking lounges, the ventilation rates in Table 403.3 are based on the absence of smoking in occupiable spaces. Where smoking is anticipated in a space other than a smoking lounge, the ventilation system serving the space shall be designed to provide ventilation over and above that required by Table 403.3 in accordance with accepted engineering practice.

#### Exceptions:

1. The occupant load is not required to be determined, based on the estimated maximum occupant load rate indicated in Table 403.3, where approved statistical data documents the accuracy of an alternate anticipated occupant density.
2. The occupant load used in computing the required ventilation shall be the maximum number who will occupy the room or space simultaneously during any 2-hour period.
3. Dynamic reset (Demand Controlled Ventilation). The system may be designed to reset the design outdoor air intake airflow and/or space or zone airflow as operating conditions change. These conditions include, but are not limited to:
  - 3.1. Variations in occupancy or ventilation airflow in one or more individual zones for which ventilation airflow requirements will be reset. Note: Examples of measures for estimating such variations include: occupancy scheduled by time of day, a direct count of occupants, or an estimate of occupancy or ventilation rate per person using occupancy sensors such as those based on indoor CO<sub>2</sub> concentrations.
  - 3.2. Variations in the efficiency with which outdoor air is distributed to the occupants under different ventilation system airflows and temperatures.

3.3. A higher fraction of outdoor air in the air supply due to intake of additional outdoor air for free cooling or exhaust air makeup.

**TABLE 403.3 MINIMUM VENTILATION RATES**

OCCUPANCY CLASSIFICATION	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE $R_p$ CFM/FT <sup>2a</sup>	DEFAULT OCCUPANT DENSITY #/1000 FT <sup>2a</sup>	EXHAUST AIRFLOW RATE CFM/FT <sup>2a</sup>
<b>Correctional facilities</b>				
Cells without plumbing fixtures	5	0.12	25	—
with plumbing fixtures <sup>b</sup>	5	0.12	25	1.0
Dining halls (see food and beverage service)	—	—	—	—
Guard stations	5	0.06	15	—
Day room	5	0.06	30	—
Booking/waiting	7.5	0.06	50	—
<b>Dry cleaners, laundries</b>				
Coin-operated dry cleaner	15	—	20	—
Coin-operated laundries	7.5	0.06	20	—
Commercial dry cleaner <sup>l</sup>	30	—	30	—
Commercial laundry	25	—	10	—
Storage, pick up	7.5	0.12	30	—
<b>Education</b>				
Auditoriums	5	0.06	150	—
Corridors (see public spaces)	—	—	—	—
Media center	10	0.12	25	—
Sports locker rooms <sup>b</sup>	—	—	—	0.5
Music/theater/dance	10	0.06	35	—
Smoking lounges <sup>b</sup>	60	—	70	—
Day care (through age 4)	10	0.18	25	—
Classrooms (ages 5—8)	10	0.12	25	—
Classrooms (age 9 plus)	10	0.12	35	—
Lecture classroom	7.5	0.06	65	—
Lecture hall (fixed seats)	7.5	0.06	150	—

(Continued)

**TABLE 403.3—continued MINIMUM VENTILATION RATES**

OCCUPANCY CLASSIFICATION	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE $R_p$ CFM/FT <sup>2a</sup>	DEFAULT OCCUPANT DENSITY #/1000 FT <sup>2a</sup>	EXHAUST AIRFLOW RATE CFM/FT <sup>2a</sup>
Art classroom	10	0.18	20	0.7
Science laboratories <sup>b, k</sup>	10	0.18	25	1.0
Wood/metal shops <sup>b</sup>	10	0.18	20	0.5
Computer lab	10	0.12	25	—
Multiuse assembly	7.5	0.06	100	—

Locker/dressing rooms <sup>g</sup>	—	—	—	0.25
<b>Food and beverage service</b>				
Bars, cocktail lounges	7.5	0.18	100	—
Cafeteria, fast food	7.5	0.18	100	—
Dining rooms	7.5	0.18	70	—
Kitchens (cooking) <sup>b</sup>	—	—	—	0.7
<b>Hospitals, nursing and convalescent homes</b>				
Autopsy rooms <sup>b</sup>	—	—	—	0.5
Medical procedure rooms	15	—	20	—
Operating rooms	30	—	20	—
Patient rooms	25	—	10	—
Physical therapy	15	—	20	—
Recovery and ICU	15	—	20	—
<b>Hotels, motels, resorts and dormitories</b>				
Multipurpose assembly	5	0.06	120	—
Bathrooms/toilet—private <sup>g</sup>	—	—	—	25/50 <sup>f</sup>
Bedroom/living room	5	0.06	10	—
Conference/meeting	5	0.06	50	—
Dormitory sleeping areas	5	0.06	20	—
Gambling casinos	7.5	0.18	120	—
Lobbies/prefunction	7.5	0.06	30	—
<b>Laboratories<sup>j</sup></b>				
Biological	—	1.0	—	1.0
Chemical	—	1.0	—	1.0
Industrial and nonteaching	—	1.0	—	1.0
Nonproduction chemical labs	—	1.0	—	1.0
<b>Offices</b>				
Conference rooms	5	0.06	50	—
Office spaces	5	0.06	5	—
Reception areas	5	0.06	30	—
Telephone/data entry	5	0.06	60	—
Main entry lobbies	5	0.06	10	—
<b>Private dwellings, single and multiple</b>				
Garages, common for multiple units <sup>b</sup>	—	—	—	0.75
Garages, separate for each dwelling <sup>b</sup>	—	—	—	100 cfm per car
Kitchens <sup>b</sup>	—	—	—	25/100 <sup>f</sup>
Living areas <sup>c,i</sup>	0.35 ACH but not less than 15 cfm/person	—	Based upon number of bedrooms. First bedroom, 2; each additional bedroom, 1	—
Toilet rooms and bathrooms <sup>g</sup>	—	—	—	20/50 <sup>f</sup>

(Continued)

TABLE 403.3—continued MINIMUM VENTILATION RATES

OCCUPANCY CLASSIFICATION	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE $R_a$ CFM/FT <sup>2a</sup>	DEFAULT OCCUPANT DENSITY #/1000 FT <sup>2a</sup>	EXHAUST AIRFLOW RATE CFM/FT <sup>2a</sup>
<b>Public spaces</b>				
Corridors	—	0.06	—	—
Elevator car	—	—	—	1.0
Shower room (per shower head) <sup>e</sup>	—	—	—	50/20 <sup>f</sup>
Smoking lounges <sup>b</sup>	60	—	70	—
Toilet rooms — public <sup>g</sup>	—	—	—	50/70 <sup>e</sup>
Places of religious worship	5	0.06	120	—
Courtrooms	5	0.06	70	—
Legislative chambers	5	0.06	50	—
Libraries	5	0.12	10	—
Museums (children's)	7.5	0.12	40	—
Museums/galleries	7.5	0.06	40	—
<b>Retail stores, sales floors and show room floors</b>				
Sales (except as below)	7.5	0.12	15	—
Dressing rooms	—	—	—	0.25
Mall common areas	7.5	0.06	40	—
Shipping and receiving	—	0.12	—	—
Smoking lounges <sup>b</sup>	60	—	70	—
Storage rooms	—	0.12	—	—
Warehouses (see storage)	—	—	—	—
<b>Specialty shops</b>				
Automotive motor-fuel dispensing stations <sup>b</sup>	—	—	—	1.5
Barber	7.5	0.06	25	0.5
Beauty and nail salons <sup>b, h</sup>	20	0.12	25	0.6
Embalming room <sup>b</sup>	—	—	—	2.0
Pet shops (animal areas) <sup>b</sup>	7.5	0.18	10	0.9
Supermarkets	7.5	0.06	8	—
<b>Sports and amusement</b>				
Disco/dance floors	20	0.06	100	—
Bowling alleys (seating areas)	10	0.12	40	—
Game arcades	7.5	0.18	20	—
Ice arenas without combustion engines	—	0.30	—	0.5
Gym, stadium, arena (play area)	—	0.30	—	—
Spectator areas	7.5	0.06	150	—
Swimming pools (pool and deck area)	—	0.48	—	—
Health club/aerobics room	20	0.06	40	—
Health club/weight room	20	0.06	10	—
<b>Storage</b>				
Repair garages, enclosed parking garages <sup>b, d</sup>	—	—	—	0.75
Warehouses	—	0.06	—	—

(Continued)

**TABLE 403.3—continued MINIMUM VENTILATION RATES**

OCCUPANCY CLASSIFICATION	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE $R_a$ CFM/FT <sup>2a</sup>	DEFAULT OCCUPANT DENSITY #/1000 FT <sup>2a</sup>	EXHAUST AIRFLOW RATE CFM/FT <sup>2a</sup>
<b>Theaters</b>				
Auditoriums (see education)	—	—	—	—
Lobbies	5	0.06	150	—
Stages, studios	10	0.06	70	—
Ticket booths	5	0.06	60	—
<b>Transportation</b>				
Platforms	7.5	0.06	100	—
Transportation waiting	7.5	0.06	100	—
<b>Workrooms</b>				
Bank vaults/safe deposit	5	0.06	5	—
Darkrooms	—	—	—	1.0
Copy, printing rooms	5	0.06	4	0.5
Meat processing <sup>c</sup>	15	—	10	—
Pharmacy (prep. area)	5	0.18	10	—
Photo studios	5	0.12	10	—
Computer (without printing)	5	0.06	4	—

For SI: 1 cubic foot per minute = 0.0004719 m<sup>3</sup>/s, 1 ton = 908 kg, 1 cubic foot per minute per square foot = 0.00508 m<sup>3</sup>/(s • m<sup>2</sup>), °C = ((°F) -32) /1.8, 1 square foot = 0.0929 m<sup>2</sup>.

- a. Based upon net occupiable floor area.
- b. Mechanical exhaust required and the recirculation of air from such spaces is prohibited (see Section 403.2.1, Item 4).
- c. Spaces unheated or maintained below 50°F are not covered by these requirements unless the occupancy is continuous.
- d. Ventilation systems in enclosed parking garages shall comply with Section 404.
- e. Rates are per water closet or urinal. The higher rate shall be provided where periods of heavy use are expected to occur, such as toilets in theaters, schools and sports facilities. The lower rate shall be permitted where periods of heavy use are not expected.
- f. Rates are per room unless otherwise indicated. The higher rate shall be provided where the exhaust system is designed to operate intermittently. The lower rate shall be permitted where the exhaust system is designed to operate continuously during normal hours of use.
- g. Mechanical exhaust is required and recirculation is prohibited.
- h. For nail salons, the required exhaust shall include ventilation tables or other systems that capture the contaminants and odors at their source and are capable of exhausting a minimum of 50 cfm/ft<sup>2</sup> per station.
- i. For R-2 buildings less than 125 feet in height, outdoor ventilation air provided by mechanical means serving dwelling units designed to exceed 100 cfm per dwelling unit, whether intermittent or continuous, shall be required. For buildings 125 feet and greater, outdoor ventilation air shall be provided by mechanical means when the sum of the exhaust designed to exceed 75 cfm, whether continuous or intermittent, per dwelling unit. Manually operated openable exterior wall openings shall not be used to provide outside ventilation air except where calculations are submitted showing that such openings are located at or below the lowest calculated neutral pressure plane (calculated at the winter outdoor design temperature, and taking into account a composite mass flow air balance of the building including all mechanical systems).
- j. During unoccupied hours the ventilation rate and exhaust rates may be reduced to 0.5 cfm/ft<sup>2</sup>.
- k. When an educational science laboratory is occupied and hoods are not in use and hazardous materials are not present, then ventilation rates shall be consistent with actual use of the space, but not less than 0.5 cfm/ft<sup>2</sup>.

I. See Section 502.6 for additional requirements.

### 403.3.1 Zone Outdoor Airflow

The minimum outdoor airflow required to be supplied to each zone shall be determined as a function of the occupancy classification and space air distribution effectiveness in accordance with Sections 403.3.1.1 through 403.3.1.3.

#### 403.3.1.1 Breathing Zone Outdoor Airflow

The outdoor airflow rate required in the breathing zone ( $V_{bz}$ ) of the occupiable space or spaces in a zone shall be determined in accordance with Equation 4-1.

$$V_{bz} = R_p P_z + R_a A_z \quad \text{(Equation 4-1)}$$

where:

$A_z$	=	Zone floor area: the net occupiable floor area of the space or spaces in the zone.
$P_z$	=	Zone population: the number of people in the space or spaces in the zone.
$R_p$	=	People outdoor air rate: the outdoor airflow rate required per person from Table 403.3.
$R_a$	=	Area outdoor air rate: the outdoor airflow rate required per unit area from Table 403.3.

#### 403.3.1.2 Zone Air Distribution Effectiveness

The zone air distribution effectiveness ( $E_z$ ) shall be determined using Table 403.3.1.2.

**TABLE 403.3.1.2 ZONE AIR DISTRIBUTION EFFECTIVENESS<sup>a,b,c,d,e</sup>**

AIR DISTRIBUTION CONFIGURATION	$E_z$
Ceiling or floor supply of cool air	1.0 <sup>f</sup>
Ceiling or floor supply of warm air and floor return	1.0
Ceiling supply of warm air and ceiling return	0.8 <sup>g</sup>
Floor supply of warm air and ceiling return	0.7
Makeup air drawn in on the opposite side of the room from the exhaust and/or return	0.8
Makeup air drawn in near to the exhaust and/or return location	0.5

For SI: 1 foot = 304.8 mm, 1 foot per minute = 0.00506 m/s,  
 $^{\circ}\text{C} = ((^{\circ}\text{F}) - 32) / 1.8$ .

- a. "Cool air" is air cooler than space temperature.
- b. "Warm air" is air warmer than space temperature.
- c. "Ceiling" includes any point above the breathing zone.
- d. "Floor" includes any point below the breathing zone.
- e. "Makeup air" is air supplied or transferred to a zone to replace air removed from the zone by exhaust or return systems.
- f. Zone air distribution effectiveness of 1.2 shall be permitted for systems with a floor supply of cool air and ceiling return, provided that low-velocity displacement ventilation achieves unidirectional flow and thermal stratification.
- g. Zone air distribution effectiveness of 1.0 shall be permitted for systems with a ceiling supply of warm air, provided that supply air temperature is less than 15°F above space temperature and provided that the 150-foot-per-minute supply air jet reaches to within 4<sup>1</sup>/<sub>2</sub> feet of floor level.

### 403.3.1.3 Zone Outdoor Airflow

The zone outdoor air flow rate ( $V_{Oz}$ ), shall be determined in accordance with Equation 4-2.

$$V_{Oz} = \frac{V_{bz}}{E_z} \quad \text{(Equation 4-2)}$$

### 403.3.2 System Outdoor Airflow

The outdoor air required to be supplied by each ventilation system shall be determined in accordance with Sections 403.3.2.1 through 403.3.2.3 as a function of system type and zone outdoor airflow rates.

#### 403.3.2.1 Single Zone Systems

Where one air handler supplies a mixture of outdoor air and recirculated return air to only one zone, the system outdoor air intake flow rate ( $V_{Oz}$ ) shall be determined in accordance with Equation 4-3.

$$V_{Oz} = V_{Oz} \quad \text{(Equation 4-3)}$$

#### 403.3.2.2 100-Percent Outdoor Air Systems

Where one air handler supplies only outdoor air to one or more zones, the system outdoor air intake flow rate ( $V_{Oz}$ ) shall be determined using Equation 4-4.

$$V_{Oz} = \sum \text{all zones } V_{Oz} \quad \text{(Equation 4-4)}$$

#### 403.3.2.3 Multiple Zone Recirculating Systems

Where one air handler supplies a mixture of outdoor air and recirculated return air to more than one zone, the system outdoor air intake flow rate ( $V_{Oz}$ ) shall be determined in accordance with Sections 403.3.2.3.1 through 403.3.2.3.4.

##### 403.3.2.3.1 Primary Outdoor Air Fraction

The primary outdoor air fraction ( $Z_p$ ) shall be determined for each zone in accordance with Equation 4-5.

$$Z_p = V_{Oz} / V_{pz} \quad \text{(Equation 4-5)}$$

where:

$V_{pz}$	=	Primary airflow: The airflow rate supplied to the zone from the air-handling unit at which the outdoor air intake is located. It includes outdoor intake air and recirculated air from that air-handling unit but does not include air transferred or air recirculated to the zone by other means. For design purposes, $V_{pz}$ shall be the zone design primary airflow rate, except for zones with variable air volume supply and $V_{pz}$ shall be the lowest expected primary air-flow rate to the zone when it is fully occupied.
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##### 403.3.2.3.2 System Ventilation Efficiency

The system ventilation efficiency ( $E_v$ ) shall be determined using Table 403.3.2.3.2 or Appendix A of ASHRAE 62.1.

**TABLE 403.3.2.3.2 SYSTEM VENTILATION EFFICIENCY<sup>a,b</sup>**

Max ( $Z_p$ )	$E_v$
≤ 0.15	1
≤ 0.25	0.9
≤ 0.35	0.8
≤ 0.45	0.7
≤ 0.55	0.6
≤ 0.65	0.5
≤ 0.75	0.4
≤ 0.75	0.3

- a.  $Max(Z_p)$  is the largest value of  $Z_p$  calculated using Equation 4-5 among all the zones served by the system.
- b. Interpolating between table values shall be permitted.

**403.3.2.3.3 Uncorrected Outdoor Air Intake**

The uncorrected outdoor air intake flow rate ( $V_{OU}$ ) shall be determined in accordance with Equation 4-6.

$$V_{ou} = D \sum \text{all zones } R_p P_z + \sum \text{all zones } R_d A_z \tag{Equation 4-6}$$

where:

$D$	=	Occupant diversity: the ratio of the system population to the sum of the zone populations, determined in accordance with Equation 4-7.
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$$D = P_s / \sum \text{all zones } P_z \tag{Equation 4-7}$$

where:

$P_s$	=	System population: The total number of occupants in the area served by the system. For design purposes $P_s$ shall be the maximum number of occupants expected to be concurrently in all zones served by the system.
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**403.3.2.3.4 Outdoor Air Intake Flow Rate**

The outdoor air intake flow rate ( $V_{OI}$ ) shall be determined in accordance with Equation 4-8.

$$V_{oi} = V_{ou} / E_v \tag{Equation 4-8}$$

**403.4 Short-Term Conditions**

If it is known that peak occupancy will be of short duration and/or ventilation will be varied or interrupted for a short period of time, the design may be based on the average conditions over a time period  $T$  determined by Equation 4-9.

$$T = 3v/V_{bz} \tag{Equation 4-9} \text{ (US)}$$

$$T = 50v/V_{bz} \tag{Equation 4-9} \text{ (SI)}$$

where:

$T$	=	average time period, minutes
$V$	=	the volume of the zone of which averaging is being applied, cubic feet
$V_{bz}$	=	the breathing zone outdoor airflow calculated using Equation 4-1 and design value of the zone population $P_z$ cfm

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

1. Zone with fluctuating occupancy: the zone population ( $P_z$ ) may be averaged over time,  $T$ .
2. Zone with intermittent interruption of supply air: the average outdoor airflow supplied to breathing zone over time  $T$  shall be no less than the breathing zone outdoor airflow ( $V_{bz}$ ) calculated using Equation 4-1.
3. A system with intermittent closure of outdoor air intake: the average outdoor air intake over time,  $T$  shall be no less than the minimum outdoor air intake ( $V_{OI}$ ) calculated using Equation 4-3, 4-4 or 4-8, as appropriate.



**403.5 Exhaust Ventilation**

Exhaust airflow rate shall be provided in accordance with the requirements in Table 403.3. Exhaust makeup air shall be permitted to be any combination of outdoor air, recirculated air and transfer air, except as limited in accordance with Section 403.2.

**403.6 System Operation**

The minimum flow rate of outdoor air that the ventilation system must be capable of supplying during its operation shall be permitted to be based on the rate per person indicated in Table 403.3 and the actual number of occupants present.

**403.7 Variable Air Volume System Control**

Variable air volume air distribution systems, other than those designed to supply only 100-percent outdoor air, shall be provided with controls to regulate the flow of outdoor air. Such control system shall be designed to maintain the flow rate of outdoor air at a rate of not less than that required by Section 403.3 over the entire range of supply air operating rates.

**403.8 Balancing**

The ventilation air distributing system shall be provided with means to adjust the system to achieve at least the minimum ventilation airflow rate as required by Sections 403.3 and 403.4. Ventilation systems shall be balanced by an approved method. Such balancing shall verify that the ventilation system is capable of supplying and exhausting the airflow rates required by Sections 403.3 and 403.4.