BSR/ASHRAE Addendum ab
to ANSI/ASHRAE Standard 62.1-2022

Public Review Draft

Proposed Addendum ab to Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality

Fifth Public Review (March 2023)
(Draft shows Proposed Independent Substantive Changes to Previous Public Review Draft)

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FOREWORD

Using CO_2 to control outdoor air ventilation rates, called Demand Control Ventilation (DCV), has become increasingly popular to achieve energy savings in buildings that have varying occupancy rates. DCV is also a mandatory requirement for densely occupied spaces in ASHRAE Standard 90.1, but the standard provides no details how to implement DCV nor does it specifically mention CO_2. USGBC's Leadership in Energy and Environmental Design (LEED) uses CO_2 as an indicator of IAQ conditions, but it references Standard 62.1 Informative Appendix D, "Rationale for Minimum Physiological Requirements for Respiration Air Based on CO_2 Concentration." That appendix was deleted in the 2019 version of the standard because it contained outdated information that was widely misinterpreted. Specific requirements are therefore needed on how to use CO_2 concentration for DCV.

This addendum adds differential CO_2 concentration limits above ambient to Table 6-1 specifically for use with CO_2 DCV systems. The values were determined based on steady-state equations and

- *Outdoor air ventilation rates from Table 6-1 based on the default occupant density and default air temperature and pressure;*
- *Values of CO_2 generation rates based on activity level, gender, body mass, and age per ASTM D6245-2018[1] and Persily & de Jonge 2017[2];*
- *Assumptions regarding activity level and the mix of gender, body size, and age in each space based on SSPC judgment;*
- *Zone air distribution effectiveness (Ez) equal to 1.0, because the CO_2 in the space is what is being controlled and the actual airflow delivery will automatically adjust for Ez less than or more than 1.0.*

CO_2 limits shown in Table 6-1 are the differential concentration above ambient. In recognition of the uncertainty due to the range of assumptions, and for ease of use, the resulting differential CO_2 concentration limits were then rounded off to the nearest multiple of 300 ppm.

Ambient concentration can be determined with ambient CO_2 sensors but is allowed to be assumed to be 400 ppm for the following reasons:

- *400 ppm is a common assumption, e.g. see California Title 24 Energy Standards[3] and Lawrence 2008[4].*
- *400 ppm is conservative from a ventilation standpoint since few areas have consistently lower average ambient concentrations.*
- *Using a fixed value avoids the first cost and recurring calibration costs of an ambient CO_2 sensor, which for hardwired room CO_2 sensors would have to be hardwired to each room CO_2 sensor.*
- *Automatically Background Calibration (ABC) logic, which is very commonly used with commercial CO_2 sensors to automatically maintain calibration, uses 400 ppm as the ambient concentration targeted by the logic, so ambient concentration is effectively indicated as 400 ppm regardless of actual ambient concentration. Therefore, when CO_2 sensors with ABC logic are used, ambient concentration should always be assumed to be 400 ppm.*

With respect to using steady-state concentration limits for DCV, ASHRAE RP-1547[5] found that "CO_2 generation rate and odor generation rate are proportional, [so] the zone-to-discharge differential CO_2 concentration can be used as a signifier of human odors in a space". Taylor 2006[6] also explains why using steady-state CO_2 concentration limits makes sense even though zone conditions are not steady-state:

Equation 1 $$V_{bz} = R_p P_z + R_a A_z$$

Equation 11: $$V'_{ot} = \frac{R_a A_z}{E_z - \frac{R_p (C_R - C_{OA})}{8400\, m}}$$

Both Equation 11 and Equation 1, from which it was derived, are based on an assumption of steady-state conditions. In non-steady-state conditions, typical of most real-world applications, CO_2 concentration will generally lag behind changes in the actual number of occupants in the zone and changes in ventilation airflow rates. However, using Equation 11 to control outdoor air rates is still valid because the rate of generation of CO_2 by occupants should be nearly proportional to the rate of bioeffluent generation; both are generated at a rate proportional to the number of people and their activity level. It is bioeffluent (odor) concentration we are trying to control, and if the source strengths of CO_2 and bioeffluents are proportional, CO_2 concentration may be used as an indicator of bioeffluent concentration. Thus the steady-state assumption in Equation 11 is made not because the actual system is at steady-state but because the ventilation rate equation, Equation 1, is based on steady-state conditions. This steady-state relationship is simply being used to establish the relationship between CO_2 (odor) concentration and airflow setpoint in Equation 11. Therefore, while the rate of air supplied using Equation 11 will not exactly track the source strength of bioeffluents due to transient effects, it should maintain an acceptable bioeffluent concentration.

Note that the language of 6.2.6.1.3.1 to 6.2.6.1.3.3 proposed in this addendum was largely extracted from Title 24 Building Energy Efficiency Standards section 120.1(d)4.

Section 6.2.6.1.4 has been moved up to become Section 6.2.6.2. because it may be used with other dynamic controls (e.g. occupancy sensors), not just DCV.

The exception to 6.2.6.1 is moved down to become an exception to 6.2.6.1.3 since it addresses use of CO_2 for DCV.

Some occupancies have CO_2 limits listed as "NA", meaning DCV is not applicable and may not be used, in cases the SSPC did not think CO_2 DCV was appropriate for one or more of the following:

- *Animal occupancies where CO_2 may be generated by animals other than humans so CO_2 will not track human bioeffluents.*
- *Occupancies, such a laboratories, where occupant activities may be generating significant contaminants other than bioeffluents.*
- *Health care occupancies where an unknown number of infectious individuals may be present.*

Independent Substantive Changes Since Previous Public Review:

This review draft shows changes to the previous public review. These include:

- *Changing the CO_2 "setpoint" to a "maximum" limit. The term "setpoint" in the context of controls implies that the controlled variable, CO_2 concentration in this case, can oscillate around this value using control logic such as proportional + integral logic. But these CO_2 values are actually limits that the control system must always maintain space concentration to be at or below.*
- *Making it clear that DCV logic must increase ventilation proportional to zone CO_2 concentration increases above ambient. Because the people- and area-based ventilation rates are additive, the control logic cannot wait until zone CO_2 concentration nears the maximum limit before increasing ventilation.*
- *Adding variable names and equations for clarity.*
- *Adding an exception that allows CO_2 limits to be exceeded if the ventilation system is delivering at its design rate. This is consistent with the informative note in Appendix D that explains that the delta-CO_2*

limits were calculated based on many assumptions that may at times be inconsistent with actual conditions.

- *Allowing alternative DCV control logic to be used provided it can be demonstrated that it results in minimum ventilation rates being maintained. For instance, Research Project RP-1747*[7] *developed DCV logic for multiple zone systems that uses the differential between supply air and zone CO_2 concentrations, rather than outdoor air and zone CO_2 concentrations. Stanke*[8] *also showed that outdoor air does not have to be increased directly proportionally to CO_2 increases to meet required ventilation rates; more complex logic could be less conservative. This advanced logic is complex and thus listed as an exception where the viability of the logic must be demonstrated.*
- *Ensuring that ventilation zones for which DCV is being applied that serve multiple rooms must have CO_2 sensors in each room. (Note that this does not require that CO_2 sensors be installed in non-DCV zones served by the same air handler as DCV zones.)*
- *Eliminating DCV as an option ("NA" in the ΔCO2 column) for wood/metal shops and occupancies that have no occupant ventilation rate Rp.*
- *Addressing sample-draw type CO_2 sensors to be sure they sample frequently enough to stably control zone CO_2 concentration.*
- *Clarifying that ventilation zones serving multiple rooms must monitor occupancy in all rooms before occupied-standby mode can be applied.*
- *Moving the occupant density adjustment in Appendix D to the body of Section 6.2.6.1.3.2 and making it mandatory instead of optional, due to the risk of under-ventilation if actual occupant density is lower than default occupant density. This should be a minor burden on designers since their ventilation rate calculations already include their design occupant density when it differs from the default, which then can be used to make the ΔCO_2 adjustment with relatively simple equations. When this adjustment is made, it is rounded off to 100 ppm to retain a similar number of significant digits in the ΔCO_2 values in Table 6-1.*
- *Correcting a typo in the calculation of default occupant density $PD_{6.1}$ in Appendix D, now part of Section 6.2.6.1.3.2.*

References:

1. ASTM D6245-2018 *Standard Guide for using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation*
2. Persily and de Jonge, 2017, *Indoor Air*, 27: 868-879
3. California Building Energy Efficiency Standards, Title 24 Part 6
4. Lawrence, T. 2008. Selecting CO2 criteria for outdoor air monitoring. ASHRAE Journal 50(12).
5. ASHRAE Research Project RP-1547 CO2-based Demand Controlled Ventilation for Multiple Zone HVAC Systems, Final Report, September 2013
6. Taylor, S. 2006. CO2-Based DCV Using 62.1-2004, ASHRAE Journal May 2006
7. ASHRAE Research Project RP-1747: Implementation of RP-1547 CO2-based Demand Controlled Ventilation for Multiple Zone HVAC Systems in Direct Digital Control Systems; Final Report, June 2017
8. Stanke, D. Standard 62.1-2004 System Operation: Dynamic Reset Options, December 2006

[Note to Reviewers: This public review draft makes proposed independent substantive changes to the previous public review draft. These changes are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum ab to 62.1-2022

Modify Section 6.2.6.1 as shown below. Renumber existing sections accordingly.

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

6.2.6.1.1 For DCV *ventilation zones* in the occupied mode, breathing zone outdoor airflow (V_{bz}) shall be reset in response to current population. Current population estimates or indicators used in DCV control calculations shall not result in ventilation rates that are less than those required by the actual population when averaged over ~~during~~ the time ~~averaging~~ period determined in accordance with Section 6.2.5.2 or one hour, whichever is less.

6.2.6.1.2 For DCV *ventilation 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.

6.2.6.1.3 CO_2 sensors shall be permitted to be used for DCV in accordance with the following subsections.

> **Exception to 6.2.6.1.3**: CO_2-based DCV shall not be applied in zones with indoor sources of CO_2 other than occupants, or with CO_2 removal mechanisms, such as gaseous air cleaners.

6.2.6.1.3.1 CO_2 sensors shall be located in the space between 3 ft (0.9 m) and 6 ft (1.8 m) above the floor. There shall be at least one CO_2 sensor per *ventilation zone* and at least one per 5,000 ft² (460 m²) of *net occupiable floor area*. Where DCV *ventilation zones* are comprised of more than one room, each room shall have a CO_2 sensor and ventilation shall be controlled to the room requiring the most ventilation.

> **Exception to 6.2.6.1.3.1:** Other locations for CO_2 sensors are permitted if the locations are demonstrated to be accurate in measuring average CO_2 concentrations in the space breathing zone.

6.2.6.1.3.2 Demand ventilation controls shall ~~be based on maximum space CO_2 concentration setpoints above ambient concentration listed in Table 6-1 plus the outdoor air CO_2 concentration determined in accordance with Section 6.2.6.1.3.3. Where "NA" is listed in Table 6-1, CO_2 DCV shall not be used. Setpoints shall be permitted to be adjusted in accordance with Normative Appendix D.~~maintain zone CO_2 concentration less than or equal to C_{max} determined in accordance with Equation 6-12.

$$C_{max} = C_{amb} + \Delta C \qquad (6\text{-}12)$$

where

C_{amb} = the outdoor air CO_2 concentration determined in accordance with Section 6.2.6.1.3.3.

ΔC = maximum CO_2 concentration above ambient concentration. It shall be equal to $\Delta C_{6.1}$ listed in Table 6-1 if the design occupancy used to calculate the zone design ventilation rate per Section 6.2 is equal to the default occupant density listed in Table 6-1.

Where the design occupancy used to calculate the zone design ventilation rate per Section 6.2 differs from the default occupant density listed in Table 6-1, ΔC in Equation 6-12 shall be the adjusted value determined in accordance with Equation 6-13:

$$\Delta C_{adj} = \Delta C_{6.1} \frac{R_p + \frac{R_a}{PD_{6.1}}}{R_p + \frac{R_a}{PD_{des}}} \qquad 6\text{-}13$$

Where:
ΔC_{adj} = Adjusted CO_2 maximum above ambient CO_2 concentration, ppm, rounded to the nearest 100 ppm.
$\Delta C_{6.1}$ = Maximum CO_2 above ambient CO_2 concentration from Table 6-1, ppm
R_p = People Outdoor Air Rate from Table 6-1, cfm/p (L/s/p)
R_a = Area Outdoor Air Rate from Table 6-1, cfm/ft² (L/s/m²)
$PD_{6.1}$ = Default occupant density, number of people per unit area from Table 6-1, #/1000 ft² /1000 (#/100 m² /100)
PD_{des} = Design occupant density, number of people per unit area, equal to P_z/A_z where P_z and A_z are determined in accordance with Section 6.2.1.1.

Where "NA" is listed in Table 6-1, CO_2 DCV shall not be used.

Informative Note: Steady-state CO_2 concentrations are not only dependent on occupancy density, but also on activity level, gender, body mass, and age. The CO_2 values in Table 6-1 are based on assumptions of these values that are typical of the occupancy type. The activity level (met) has the greatest impact to the steady state CO_2 values. It is therefore possible that the differential CO_2 values in the space may exceed the concentrations listed in Table 6-1 even if the occupancy density and the ventilation rate meet the values listed in Table 6-1.

DCV controls shall maintain the zone ventilation rate at no less than the building component (Ra × Az) when zone CO_2 concentration is at C_{amb}. Upon a rise in measured CO2 levels above C_{amb}, ventilation shall be increased proportional to the difference between zone CO_2 concentration and C_{amb}. When the zone CO_2 concentration is equal to C_{max} , the minimum zone ventilation rate shall be equal to its design ventilation rate determined in accordance with Section 6.2 at design occupancy.

Exceptions to 6.2.6.1.3.2:

1. Zone and system ventilation rates are not required to be larger than the design ventilation rate required by Section 6.2 at design occupancy regardless of CO_2 concentration.
2. Other DCV control logic shall be permitted to be used where it can be demonstrated to comply with Section 6.2.6.1.1 under all expected operating conditions.

Informative Note: The CO_2 values in Table 6-1 are only for the purposes of implementing CO_2 DCV. They are not intended to be and should not be used as indicators of IAQ.

6.2.6.1.3.3 Outdoor air CO_2 concentration, C_{amb}, shall be determined by one of the following:

a. CO_2 concentration shall be assumed to be 400 ppm without any direct measurement; or

b. CO_2 concentration shall be dynamically measured using a CO_2 sensor located within 4 ft (1.2 m) of the outdoor air intake.

6.2.6.1.3.4 CO_2 sensors shall be certified by the manufacturer to be accurate within ±75 ppm at concentrations of 600, 1000 ppm, and 2500 ppm when measured at sea level at 77 °F (25 °C). Sensors shall be factory calibrated and certified by the manufacturer to require calibration not more frequently than once every five years. Upon detection of sensor failure, the system shall provide a signal that resets the ventilation system to supply the required minimum quantity of outdoor air (V_{bz}) to the breathing zone for the design zone population (P_z).

6.2.6.1.3.5 CO_2 sensors that sequentially sample air from multiple spaces shall sample each space no less than once every 5 minutes.

6.2.6.2 For ventilation zones in occupied standby mode, breathing zone outdoor airflow shall be permitted to be reduced to zero for the occupancy categories indicated "OS" in Table 6-1, provided that airflow is restored to V_{bz} whenever occupancy is detected. Where ventilation zones are comprised of more than one room, ventilation reduction shall be permitted only when occupancy is not detected in all rooms served by the ventilation zone and shall be restored when occupancy is detected in any room served by the ventilation zone.

Add a column to the right side of Table 6-1. The remainder of Table 6-1 is unchanged.

Table 6-1 Minimum Ventilation Rates in Breathing Zone

Occupancy Category	Maximum CO_2 ~~Setpoint~~ above Ambient, $\Delta C_{6.1}$
Animal Facilities	
Animal exam room (veterinary office)	NA
Animal imaging (MRI/CT/PET)	NA
Animal operating rooms	NA
Animal postoperative recovery room	NA
Animal preparation rooms	NA

Occupancy Category	**Maximum CO_2 ~~Setpoint~~ above Ambient, $\Delta C_{6.1}$**
Animal procedure room	NA
Animal surgery scrub	NA
Large-animal holding room	NA
Necropsy	NA
Small-animal-cage room (static cages)	NA
Small-animal-cage room (ventilated cages)	NA
Correctional Facilities	
Booking/waiting	1200
Cell	NA
Dayroom	1500
Guard stations	1200
Educational Facilities	
Art classroom	NA
Classrooms (ages 5 to 8)	600
Classrooms (age 9 plus)	600
Computer lab	600
Daycare sickroom	NA
Daycare (through age 4)	NA
Lecture classroom	1200
Lecture hall (fixed seats)	1200
Libraries	600
Media center	600
Multiuse assembly	1200
Music/theater/dance	2100
Science laboratories	NA
University/college laboratories	NA
Wood/metal shop	~~1200~~NA
Food and Beverage Service	
Bars, cocktail lounges	1200
Cafeteria/fast-food dining	900
Kitchen (cooking)	NA
Restaurant dining rooms	1500
General	
Breakrooms	1500
Coffee stations	1200
Conference/meeting	1500
Corridors	NA
Occupiable storage rooms for liquids or gels	NA
Hotels, Motels, Resorts, Dormitories	
Barracks sleeping areas	900
Bedroom/living room	600
Laundry rooms, central	NA
Laundry rooms within dwelling units	NA
Lobbies/prefunction	1500
Multipurpose assembly	1800
Miscellaneous Spaces	
Banks or bank lobbies	900
Bank vaults/safe deposit	600
Computer (not printing)	600
Freezer and refrigerated spaces (<50°F [10°C])	NA

Occupancy Category	**Maximum CO_2 ~~Setpoint~~ above Ambient, $\Delta C_{6.1}$**
Manufacturing where hazardous materials are not used	600
Manufacturing where hazardous materials are used (excludes heavy industrial and chemical processes)	NA
Pharmacy (prep. area)	900
Photo studios	NA
Shipping/receiving	700
Sorting, packing, light assembly	900
Telephone closets	~~700~~NA
Transportation waiting	1800
Warehouses	700
Office Buildings	
Breakrooms	1500
Main entry lobbies	1200
Occupiable storage rooms for dry materials	700
Office space	600
Reception areas	2100
Telephone/data entry	1800
Public Assembly Spaces	
Auditorium seating area	1800
Courtrooms	1500
Legislative chambers	1800
Libraries	600
Lobbies	1800
Museums (children's)	1800
Museums/galleries	1500
Places of religious worship	1800
Retail	
Sales (except as below)	900
Barbershop	NA
Beauty and nail salons	NA
Coin-operated laundries	900
Mall common areas	2100
Pet shops (animal areas)	NA
Supermarket	1500
Sports and Entertainment	
Bowling alley (seating)	900
Disco/dance floors	1500
Gambling casinos	1200
Game arcades	900
Gym, sports arena (play area)	900
Health club/aerobics room	1500
Health club/weight rooms	1500
Spectator areas	1500
Stages, studios	1500
Swimming (pool and deck)	~~700~~NA
~~Transient~~ Residential	
Common corridors	~~700~~NA
~~Dwelling unit~~	~~NA~~
~~Outpatient Health Care Facilities~~	
~~Birthing room~~	~~NA~~

Occupancy Category	**Maximum CO_2 ~~Setpoint~~ above Ambient, $\Delta C_{6.1}$**
~~Class 1 imaging rooms~~	~~NA~~
~~Dental operatory~~	~~NA~~
~~General examination room~~	~~NA~~
~~Other dental treatment areas~~	~~NA~~
~~Physical therapy exercise area~~	~~NA~~
~~Physical therapy individual room~~	~~NA~~
~~Physical therapeutic pool area~~	~~NA~~
~~Prosthetics and orthotics room~~	~~NA~~
~~Psychiatric consultation room~~	~~NA~~
~~Psychiatric examination room~~	~~NA~~
~~Psychiatric group room~~	~~NA~~
~~Psychiatric seclusion room~~	~~NA~~
~~Speech therapy room~~	~~NA~~
~~Urgent care examination room~~	~~NA~~
~~Urgent care observation room~~	~~NA~~
~~Urgent care treatment room~~	~~NA~~
~~Urgent care triage room~~	~~NA~~

Delete new Normative Appendix D as shown below.

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

~~NORMATIVE APPENDIX D~~
~~INDOOR CO_2 CONCENTRATION SETPOINT BASED ON OCCUPANT DENSITY~~

~~The CO_2 concentration setpoints above ambient concentration shown in Table 6-1 are based on the default occupant density listed in Table 6-1, as well as other assumptions about the space and its occupants. This appendix describes how CO_2 concentration setpoints shall be permitted to be adjusted based on actual design occupant density. This adjustment is not mandatory; however if occupancy density is lower than the default, using default CO_2 setpoint may result in underventilation.~~

~~The adjusted differential CO_2 setpoint above ambient CO_2 concentration shall be calculated per Equation D-1:~~

$$\Delta C_{adj} = \Delta C_{6.1} \frac{R_p + \frac{R_a}{PD_{6.1}}}{R_p + \frac{R_a}{PD_{des}}} \qquad \text{D-1}$$

~~Where~~
~~ΔC_{adj} = Adjusted CO_2 setpoint above ambient CO_2 concentration, ppm~~
~~$\Delta C_{6.1}$ = CO_2 setpoint above ambient CO_2 concentration from Table 6-1, ppm~~
~~R_p = People Outdoor Air Rate from Table 6-1, cfm/p (L/s/p)~~
~~R_a = Area Outdoor Air Rate from Table 6-1, cfm/ft^2 (L/s/m^2)~~
~~$PD_{6.1}$ = Default occupant density, number of people per unit area from Table 6-1, #/1000 ft^2 *1000 (#/100 m^2 *100)~~
~~PD_{des} = Design occupant density, number of people per unit area, equal to P_z/A_z where P_z and A_z are determined in accordance with Section 6.2.1.1.~~

~~***Informative Note***: Steady-state CO_2 concentrations are not only dependent on occupancy density, but also on activity level, gender, body mass, and age. The setpoints in Table 6-1 are based on assumptions of these values that are typical of the occupancy type. The activity level (met) has the greatest impact to the steady state CO_2~~

~~values. It is therefore possible that the differential CO_2 values in the space may exceed the concentrations listed in Table 6-1 even if the occupancy density and the ventilation rate meet the values listed in Table 6-1.~~