BSR/ASHRAE Addendum ab
to ANSI/ASHRAE Standard 62.1-2016

Public Review Draft

Proposed Addendum ab to Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality

Second Public Review (October 2018)
(Draft Shows Proposed Independent Substantive Changes to Previous Public Review Draft)

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

This standard is under continuous maintenance. To propose a change to the current standard, use the change submittal form available on the ASHRAE website, www.ashrae.org.

The appearance of any technical data or editorial material in this public review document does not constitute endorsement, warranty, or guaranty by ASHARE of any product, service, process, procedure, or design, and ASHRAE expressly disclaims such.

ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the 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.)

FOREWORD

Indoor CO_2 has had a prominent place in discussions of ventilation and IAQ for many years (Persily, 2015; Persily, 1997). The relevant issues include the impacts of CO_2 on building occupants (including how CO_2 concentrations relate to occupant perception of bioeffluents), the use of CO_2 to control outdoor air ventilation rates, CO_2 monitoring as an indicator of general IAQ conditions and the use of indoor CO_2 to estimate building ventilation rates.

It is also quite common to use indoor CO_2 concentrations to estimate ventilation rates per person based on a single-zone mass balance of CO_2, though in many cases without acknowledgement of the assumptions on which it is based (ASTM, 2012; Persily, 1997). In a ventilated space with a uniform CO_2 concentration, the ventilation rate and CO_2 concentration are related under steady-state conditions assuming that the generation rate, ventilation rate and outdoor CO_2 concentration are all constant over the mass balance analysis period. This relationship has been discussed in ASHRAE Standard 62 since 1981 (ASHRAE, 1981), in which the steady-state equation is presented as follows:

$$Q_o = \frac{G}{C_{in,ss} - C_{out}}$$

where Q_o is the outdoor air ventilation rate per person, G is the CO_2 generation rate per person, $C_{in,ss}$ is the steady-state indoor CO_2 concentration and C_{out} is the outdoor CO_2 concentration. This steady-state relationship, sometimes referred as the peak CO_2 approach, is essentially an application of the constant injection tracer gas method as described in ASTM E741 (2011). It must therefore abide by the following assumptions to yield a valid air change rate: the CO_2 generation rate is known, constant, and uniform throughout the building being tested; the CO_2 concentration is uniform throughout the building and has achieved steady state; the outdoor CO_2 concentration is known and constant; and, the outdoor air ventilation rate is constant.

[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 <u>underlining</u> (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 previous draft 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 substantive changes.]

Addendum ab to 62.1-2016

Add a new Section 6.2.7.1.3 as shown below. Renumber following sections as applicable.

<u>6.2.7.1.3 CO_2 values for DCV control.</u> <u>When CO_2 concentrations are used for demand control ventilation, calculations shall be made using Normative Appendix D.</u>

Revise Normative Appendix D as shown below.

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

NORMATIVE APPENDIX D
ESTIMATION OF ~~STEADY-STATE~~ INDOOR CO_2 CONCENTRATIONS BASED ON ~~PER PERSON~~ VENTILATION RATES AND OCCUPANT CHARACTERISTICS

[…]

D1.2.3 Body Mass. Values of body mass shall be obtained from Table D1.2.3 by calculating based upon expected occupancy of males and females using Table D1.2.4 and Table D1.2.5. Table D1.2.3 ~~The table~~ is a table of body weight data for males and females combined from the EPA Exposure Factors Handbook. Table D1.2.4 and D.1.2.5 are body weight data for males and females.

[…]

Table D1.2.4. Body weight data for males from 2011 EPA Exposures Factors Handbook

Table 8-4. Mean and Percentile Body Weights (kg) for Males Derived From NHANES (1999–2006)

Age Group	*N*	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	88	4.9	3.6	3.6	4.0	4.4	4.8	5.5	5.8	6.2	6.8
1 to <3 months	153	6.0	4.6	5.0	5.1	5.4	6.1	6.8	7.0	7.2	7.3
3 to <6 months	255	7.6	5.9	6.4	6.6	6.9	7.5	8.2	8.6	8.8	9.1
6 to <12 months	472	9.4	7.3	7.9	8.2	8.5	9.4	10.3	10.6	10.8	11.5
1 to <2 years	632	11.6	9.0	9.7	10.0	10.5	11.5	12.6	13.2	13.5	14.3
2 to <3 years	558	14.1	11.4	12.0	12.2	12.8	14.0	15.2	15.9	16.4	17.0
3 to <6 years	1,158	18.8	13.5	14.4	14.9	15.9	18.1	20.8	22.6	23.8	26.2
6 to <11 years	1,795	31.9	20.0	21.8	22.9	24.8	29.6	36.4	41.2	45.2	51.4
11 to <16 years	2,593	57.6	33.6	36.3	38.9	44.2	55.5	66.5	75.5	81.2	91.8
16 to <21 years	2,462	77.3	54.5	57.6	60.0	63.9	73.1	86.0	96.8	104.0	113.0
21 to <30 years	1,359	84.9	58.7	63.0	66.2	70.7	81.2	94.0	103.0	111.0	123.0
30 to <40 years	1,445	87.0	61.1	65.7	68.7	73.8	84.0	96.5	104.0	110.0	124.0
40 to <50 years	1,545	90.5	64.9	69.5	73.0	77.7	87.4	99.7	109.0	114.0	125.0
50 to <60 years	1,189	89.5	64.1	68.8	71.4	77.0	87.8	99.8	107.0	112.0	123.0
60 to <70 years	1,360	89.1	63.4	67.5	71.6	77.2	86.9	99.4	108.0	113.0	120.0
70 to <80 years	1,079	83.9	60.6	64.6	68.3	73.1	82.1	93.8	98.6	104.0	113.0
Over 80 years	662	76.1	56.7	60.6	63.9	67.2	75.1	84.0	89.4	92.5	100.0

Source: U.S. EPA Analysis of NHANES 1999–2006 data.

Table D1.2.5. Body weight data for females from 2011 EPA Exposures Factors Handbook

Table 8-5. Mean and Percentile Body Weights (kg) for Females Derived From NHANES (1999–2006)

Age Group	*N*	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	70	4.6	3.6	4.0	4.1	4.2	4.6	4.9	5.0	5.2	5.9
1 to <3 months	131	5.7	4.3	4.6	4.74	5.1	5.5	6.4	6.6	6.9	7.3
3 to <6 months	234	7.2	5.5	5.9	6.2	6.4	7.2	7.9	8.2	8.4	9.0
6 to <12 months	455	9.0	7.1	7.3	7.6	8.0	8.9	9.8	10.3	10.6	11.2
1 to <2 years	544	11.1	8.7	9.1	9.4	10.0	11.1	12.2	12.9	13.2	13.7
2 to <3 years	586	13.5	10.5	11.0	11.5	12.1	13.2	14.6	15.5	16.2	17.1
3 to <6 years	1,160	18.3	13.5	14.3	14.7	15.6	17.5	19.7	21.3	23.2	26.2
6 to <11 years	1,798	31.7	19.3	20.9	22.0	23.9	29.0	37.3	43.1	46.7	53.4
11 to <16 years	2,704	55.9	34.9	38.6	41.6	45.7	53.3	62.8	70.7	76.5	86.3
16 to <21 years	2,389	65.9	46.2	48.6	51.1	54.5	61.5	73.3	83.4	89.9	99.7
21 to <30 years	1,873	71.9	48.0	51.4	53.8	57.8	67.9	81.4	90.2	98.7	109.0
30 to <40 years	1,731	74.8	50.9	54.0	56.2	60.0	70.2	85.0	95.1	104.0	113.0
40 to <50 years	1,576	77.1	51.7	54.7	57.3	61.7	72.7	88.0	97.8	105.0	118.0
50 to <60 years	1,198	77.5	52.2	55.7	57.9	62.8	73.6	87.7	97.7	105.0	117.0
60 to <70 years	1,422	76.8	51.9	56.5	59.2	63.9	73.9	86.6	95.4	102.0	112.0
70 to <80 years	954	70.8	49.6	53.3	55.7	60.3	69.0	79.4	85.6	91.4	98.2
Over 80 years	768	64.1	45.5	48.7	51.3	54.9	62.8	71.8	77.0	80.5	89.1

Source: U.S. EPA Analysis of NHANES 1999–2006 data.

D1.2.4 Value of M. The level of physical activity for the occupants shall be estimated based on values in Tables D1.2.4.1 ~~or D1.2.4.2~~.

~~**Table 1.2.4.1. *M* values for various activities** [5]~~

~~**Activity**~~	~~**Males**~~		~~**Females**~~	
	~~**Average *M***~~	~~***M* Range**~~	~~**Average *M***~~	~~***M* Range**~~
~~Aerobic dancing – low intensity~~	~~3.51~~		~~4.24~~	
~~Aerobic dancing – high intensity~~	~~7.93~~		~~8.31~~	
~~Calisthenics~~	~~5.44~~			
~~Child care (unspecified)~~			~~2.5~~	
~~Climbing stairs~~	~~5.0~~			
~~Dancing~~	~~5.0~~		~~5.09~~	
~~Eating and drinking~~	~~1.4~~		~~1.6~~	
~~Housework (unspecified)~~			~~2.8~~	~~2.5 to 3.0~~
~~Office worker – Filing~~	~~1.3~~		~~1.5~~	
~~Office worker – Reading~~	~~1.3~~		~~1.5~~	
~~Office worker – Sitting at desk~~	~~1.3~~			
~~Office worker – Standing/moving around~~	~~1.6~~			
~~Office worker – Typing~~	~~1.8~~		~~1.8~~	
~~Office worker – Writing~~	~~1.4~~		~~1.4~~	

~~Reading~~	~~1.22~~		~~1.25~~	
~~Sleeping~~	~~1.0~~		~~1.0~~	
~~Sitting quietly~~	~~1.2~~		~~1.2~~	
~~Sitting on a bus/train~~	~~1.2~~			
~~Standing~~	~~1.4~~		~~1.5~~	
~~Walking around/strolling~~	~~2.1~~	~~2.0 to 2.2~~	~~2.5~~	~~2.1 to 2.9~~
~~Walking quickly~~	~~3.8~~			
~~Walking slowly~~	~~2.8~~	~~2.8 to 3.0~~	~~3.0~~	

Table 1.2.4.1 ~~1.2.4.2~~. Values of physical activity levels (*M*) [4]

Activity	***M***	**Range**
Calisthenics – light effort	2.8	
Calisthenics – moderate effort	3.8	
Calisthenics – vigorous effort	8.0	
Child care		2.0 to 3.0
Cleaning, sweeping – moderate effort	3.8	
Custodial work – light	2.3	
Dancing – aerobic, general	7.3	
Dancing – general	7.8	
Health club exercise classes – general	5.0	
Kitchen activity – moderate effort	3.3	
Lying or sitting quietly		1.0 to 1.3
Sitting reading, writing, typing	1.3	
Sitting at sporting event as spectator	1.5	
Sitting tasks, light effort (e.g. office work)	1.5	
Sitting quietly in religious service	1.3	
Sleeping	0.95	
Standing quietly	1.3	
Standing tasks, light effort (e.g. store clerk, filing)	3.0	
Walking, less than 2 mph, level surface, very slow	2.0	
Walking, 2.8 mph to 3.2 mph, level surface, moderate pace	3.5	

[…]

D2. DYNAMIC

The purpose of this section of the appendix is to describe the estimation of dynamic changes in indoor carbon dioxide concentrations for various changes in room conditions.

Informative Note: Since the following are single-zone equations, CO2 transport from adjoining spaces is being ignored, and therefore the equation will not be valid if air flows into the space from adjoining spaces at different CO_2 concentrations.

D.2.1 Dynamic Estimation of Zone Occupancy:

When CO2 is used to determine zone occupancy, Equation D.2.1.1 shall be used.

$$Pz = (v \times (CRA\text{-}CRA\text{-}1)/\Delta\tau + Vpz \times (CRA\text{-}CS)) / (G \times 10^6) \quad \text{(D2.1.1)}$$

where,

Pz is the number of people occupying the zone.
G is the generation rate of CO_2 in the zone from the representative population expressed per person, (L/s or cfm)

Vpz is the primary supply flow rate to the zone, (L/s or cfm)
v is the zone volume, (ft^3 or L^3)
Cs is the concentration of CO_2 in the supply air, (ppmv)
CRA is the concentration of CO_2 in the return air (ppmv)
CRA-1 is the concentration of CO_2 in the return air one time-step back (ppmv)
$\Delta\tau$ is the time step (min or sec)

D.2.2 General Dynamic CO_2 Estimation: Equation D.2.2[D-10] shall be used when calculating CO2 concentration for any dynamic control or evaluation not using D2.2.1.

$$N + VpzCs - (Vpz - V'ot)\ CRA - V'ot\ CR = v\ \partial\ CR/\partial\ t \qquad \text{(D2.2.1)}$$

where,
N is the generation rate of CO_2 in the zone, (L/s or cfm)
Vpz is the primary supply flow rate to the zone, (L/s or cfm)
V'ot is the outdoor air rate escaping the zone through exfiltration. This air is made up by outdoor air from the air handling unit. (L/s or cfm)
v is the zone volume, (ft^3 or L^3)
Cs is the concentration of CO_2 in the supply air (ppmv),
CR is the concentration of CO_2 in the room at breathing level (ppmv), and
CRA is the concentration of CO_2 in the return air (ppmv)

N shall be determined using Equation D2.2.2.

$$N = \sum_{i=1}^{i=Pz} Pi * Gi \qquad \text{(D2.2.2)}$$

where,
Gi is the generation rate of CO_2 in the zone from the ith person, (L/s or cfm)

Informative Note: Figure D.2 illustrates the zone for equations where the control volume is the boundary of the illustrated room.

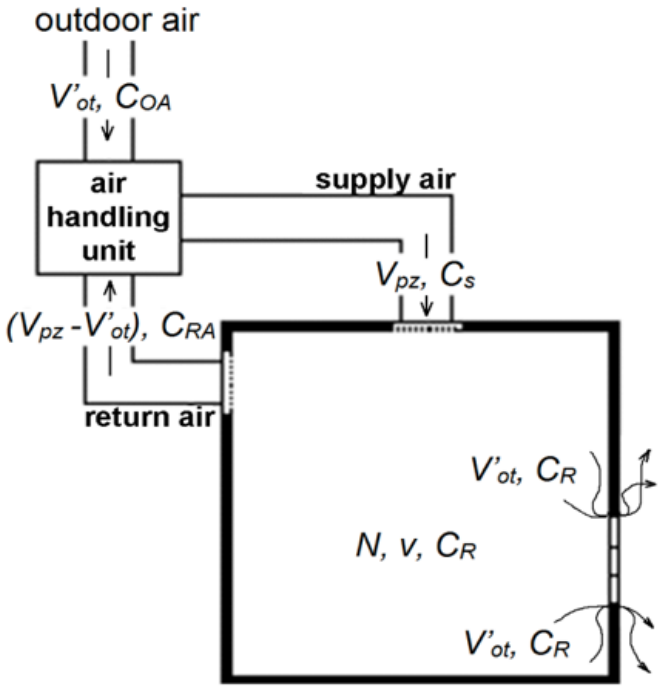

Figure D.2

D3~~D2~~. NORMATIVE REFERENCES

D-1. ASTM D6245-2018 *Standard Guide for using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation*

D4. INFORMATIVE REFERENCES

D-2. Persily and de Jonge, 2017, *Indoor Air*, 27: 868-879

D-3. Exposure Factors Handbook. Washington DC: U.S. Environmental Protection Agency, EPA/600/R-09/052F; 2011

D-4. ~~Ainsworth et al. (2011)~~ Ainsworth B, Haskell W, Herrmann S, et al. The compendium of physical activities tracking guide. Healthy Lifestyles Research Center, College of Nursing & Health Innovation, Arizona State University. 2011. https://sites.google.com/site/compendiumofphysicalactivities/.

D-5. ~~FAO 2001~~ FAO Human Energy Requirements.. Report of a joint FAO/WHO/UNU expert consultation Geneva: Food and Agriculture Organization of the United Nations. Food and Nutrition Technical Report Series 1; 2001.

D-6. ~~Schofield 1985~~ Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr. 1985;39C(Suppl 1):5-41.

D-7. Black AE, Prentice AM, Coward WA. Use of food quotients to predict respiratory quotients for the double-labelled water method of measuring energy expenditure. Hum Nutr Clin Nutr. 1986;40C:381-391.

D-8. Wright JD, Wang C-Y. Trends in Intake of Energy and Macronutrients in Adults from 1999-2000 Through 2007-2008. Hyattsville MD: Centers for Disease Control and Prevention, National Center for Health Statistics; 2010.

D-9 Mumma, S.A., Transient Occupancy Ventilation by Monitoring CO2, *IAQ Applications*, ASHRAE, Atlanta, GA, 2004

D-10 *Standard 62.1 User's Manual*, ASHRAE, Atlanta, GA., 2016.