MINUTES

BOARD OF DIRECTORS MEETING

ORLANDO, FL
Wednesday, February 12, 2025

Approved by the Board of Directors on May 28, 2025.

TABLE OF CONTENTS

Board of Directors Meeting

Wednesday, February 12, 2025

PRINCIPAL APPROVED MOTIONS

Board of Directors Meeting

Wednesday, February 12, 2025

No. - Pg.	Motion
1 - 5	Members Council recommends to the Board of Directors that a new Presidential Initiative Coordinator position be added as a permanent member of the YEA Committee roster.
2 - 5	Members Council recommends to the Board of Directors to allow Affiliate Members to hold an officer and/or chair position at the Chapter level, with the exception of the President, President-Elect, and Treasurer.
4 - 8	The ASHRAE Board of Directors (BOD) approve changes to the Publications Committee's Rules of the Board (ROB) as shown in ATTACHMENT A.
5 - 9	The following be approved as a consent agenda: ➢ Technology Council recommends to the Board of Directors that the Rules of the Board 1.201.004, *Policy and Definitions of ASHRAE Standards and Related Documents*, be revised as shown below: **1.201.004 Policy and Definitions of ASHRAE Standards and Related Documents** 1.201.004.2 Place emphasis on development of documents that establish ASHRAE as the leader in HVAC&R technology, providing state-of-the-art best practice guidance that advances the arts and sciences of our industry. ~~Such guidelines and state of the art standards should normally be written in informative language.~~ ➢ Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.003.3, *Operation*, be revised as shown below: **2.425.003.3** A. All ASHRAE standards intended for ANSI designation shall be submitted for ANSI approval as American National Standards. ➢ Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.004.2, *Policy on Standards Committee Document Development*, be approved as shown below: **2.425.004.2** Consensus standards define minimum values or acceptable performance, whereas other documents, such as guidelines or design guides, offer practical guidance, best practices, or encourage enhanced performance. ➢ Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.008, *Strategic Plan*, be approved as shown below: **2.425.008 Strategic Plan** This committee shall ~~develop procedures for recommending~~

	~~updates to the strategic plan on a continuous basis. As a minimum the committee shall~~ submit a report to the council prior to the Annual Meeting that~~.~~ ~~The report~~ includes the ~~current~~ status of each activity which supports the fulfillment of the committee's assignments under the strategic plan. The committee shall report to the council all recommendations for changes to the strategic plan as provided by the committee's constituents prior to the Annual Meeting.
6 – 10	Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.003.6, *Operation*, be approved as shown below: **2.425.003.6** D. Formation of all new standard project committees and titles, purposes and scopes, shall be approved by the ~~Board of Directors~~ Technology Council or its designee before the project committees take action.
7 - 10	Technology Council recommends to the Board of Directors that all ASHRAE Regions with Chapters outside United States and Canada appoint a liaison (Regional position) who will work closely with the GTIC to help in interaction with the ASHRAE Chapters in their Region and help promote exchange of ASHRAE technical resources to meet its objectives.
8 - 11	Tech Council recommends that the Board of Directors approve the revised *Indoor Carbon Dioxide* position document (PD) as shown in ATTACHMENT B.
9 - 11	The Society Rules Committee recommends to the Board of Directors that the below changes to ROB Section 2.415.003.1, *Nominating General Requirements* be approved as presented: **2.415 NOMINATING COMMITTEE** … 2.415.003.1 General Requirements D. All nominees for Director shall be apprised fully of their duties and responsibilities, and of the time and expense involved in the execution thereof. (62-11-03-26) E. The Nominating Committee shall require a self-certification letter annually from all society officer nominees. (21-02-04-01/15-07-01-19) F. Executive session protocols shall be considered enforced for any candidate consideration discussions between current nominating committee members during, or after, formal Nominating Committee meetings. Such discussions held at the discretion of the members shall be done in a confidential manner and not enjoin any other non-members in the discussion.

MINUTES
BOARD OF DIRECTORS MEETING
Wednesday, February 12, 2025

MEMBERS PRESENT:
Dennis Knight, President
Bill McQuade, President-Elect
Sarah Maston, Treasurer
Devin Abellon, Vice President
Wade Conlan, Vice President
Ken Fulk, Vice President
Chandra Sekhar, Vice President
Jeff Littleton, Secretary
Charles Bertuch, Region I DRC
Genevieve Lussier, Region II DRC
Sherry Abbott-Adkins, Region III DRC
Bryan Holcomb, Region IV DRC
Jim Arnold, Region V DRC
Susanna Hanson, Region VI DRC
Scott Peach, Region VII DRC
Joe Sanders, Region VIII DRC
Jonathan Smith, Region IX DRC
Buzz Wright, Region X DRC
Rob Craddock, Region XI DRC
Tulia Rios, Region XII RMCR
Cheng Wee Leong, Region XIII DRC
Mahroo Eftekhari, Region XIV DRC
Richie Mittal, Region XV DRC
Bassel Anbari, RAL DRC
Carrie Brown, DAL
Doug Cochrane, DAL
Blake Ellis, DAL
Luke Leung, DAL
Patrick Marks, DAL
Corey Metzger, DAL
Heather Schopplein, DAL
Wei Sun, DAL
David Yashar, DAL

GUESTS PRESENT:
Iian Aberman
Jonathan Alo
Fabio Clavijo
Joel Deddens
Jim Earley
Peter Ernzen
Christine Miner
Maggie Moninski
Michael Patton
Erica Powell
Patrick Ryan
Matthew Theriault
Steven Gerazounis
Jeffery Hurd
Seth Kunkel
Francis Mills
Juliana Velez

STAFF PRESENT:
Candace Denton, Sr. Manager - Board Services
Chandrias Jolly, Manager - Board Services
Vanita Gupta, Director – Marketing
Lizzy Seymour – Director – Member Services
Mark Owen, Director - Publications & Education
Kirstin Pilot, Director - Development
Stephanie Reiniche, Director - Technology
Alice Yates, Director - Government Affairs
Craig Wright, Director of Finance

CALL TO ORDER

The meeting was called to order at 2:00 pm.

VALUE STATEMENT

Mr. Knight read the value statement and advised that the full code of ethics, core values and diversity statements were available online.

ROLL CALL/INTRODUCTIONS

Members, guests and staff introduced themselves and were in attendance as noted above.

Mr. Knight noted that Region XII RMCR, Tulia Rios, was the Region XII DRC alternate in Mr. Constantinide' s absence. Ms. Rios would have voice but no vote during the meeting.

REVIEW OF MEETING AGENDA

Mr. Knight reviewed the meeting agenda. There were no changes or additions.

2025 WINTER CONFERENCE REPORT

Mr. Littleton congratulated the BOD on a terrific meeting. He asked staff directors to provide updates on conference activities in their respective areas. A summary of those updates is below:

(Lizzy Seymour, Member Services)

Registration:

	2025 Orlando	**2024 Chicago**	**2023 Atlanta**	**2022 Vegas**	**2020 Orlando**
In-Person	2828	2860	2368	1437	2932
Virtual	154	191	244	590	--
Total	2982	3044	2612	2027	2932
Committee Meeting Only	807	747	777	797	--
Combined Total	3789	3791	3389	2824	
Registration	$182,914	$168,518	$132,726	$101,527	$165,954
Bookstore	$71,957*	$58,455	$77,752	$37,060	$112,723

Total badges picked up: 2,485 in-person and 673 committee meeting only.

Most popular livestreamed session was *Seminar 36: Interdisciplinary Dimensions of Occupant Behavior, Indoor Environmental Quality for Building Health* with 41 virtual and 45 in-person attendees

Technical Program:

Most Popular In-Person Sessions	**# of Attendees**
Seminar 13: Low and Ultra-low GWP Refrigerants and Equipment to comply with Current and Future Decarbonization Efforts	250
Seminar 8: Earth, Heat and Ice: Expanding the Effectiveness of Geothermal Systems Using Ice Storage	215
Seminar 42: The Wonderful World of Dedicated Outdoor Air Systems and Energy Recovery Equipment	201
Seminar 25: LIVESTREAM: Energy Storage Solutions to Enhance Building and Grid Resilience	190
Seminar 11: LIVESTREAM: Advances in AI Technologies for the Buildings Industry	171

There were 17 livestreamed technical sessions, 2 virtual sessions hosted on WebEx, and 109 in-person technical sessions.

There were 43 virtual meetings held in advance of the conference, 415 in-person/hybrid meetings held at the conference; for a total of 458 meetings.

The Orlando Conference had 6 sponsoring companies - $46,650 gross total and $37,320 net total. Sponsorship totals were only $7,500 shy of the 2024 Winter Conference sponsorship total.

Sponsor	**Package**
JCI Applied	Tech Talk $9,300
Johnson Controls	Tech Talk $9,300
Xylem	YEA Hospitality $7,650
BACnet International	Swag $7,300
Lubrizol	Tech Talk $9,300
CASPR	Base $3,800

The Hilton Orlando had a 87$ hotel pick up for a total of 4,436 room nights sold.

(Mark Owen – Publications and Education)

Conference and Expo Bookstores:

The total combined sales from the bookstore at the hotel and the Expo was $71,957, which is about $2,000 better than Chicago 2024.

Top sellers were – *10th Edition Pocket Guides, Standard 209-2024, Standard 202-2024, Standard 15-2024 packaged with Standard 34-2024, Standard 111-2024, Guideline 36-2024, all Handbooks, ASHRAE Guide for Buildings in Hot and Humid Climates, 2nd Edition.*

ALI Courses:

The total for ALI course registrations was 670 (532 members and 139 nonmembers), which was 138 more than Chicago 2024 and 64 fewer than Atlanta 2023.

The revenue total of $156,687 was about $44,000 more than Chicago 2023 and about $9,000 more than Atlanta 2023. For context, the average revenue for the last five years (not counting missing Chicago 2021) is about $150,000, but that average is skewed upward a bit by Orlando 2020 which brought in $230,000. Without Orlando 2020, the average of the four conferences since then is about $130,000.

Courses with the most registrations:

1. *Changing Environments and Loads for Data Centers*
2. *Guideline 36: Best Class of HVAC Control Sequences*
3. *V in HVAC – Health and Energy Improvements Using the Indoor Air Quality Procedure*

Previous Winter Conference Course Stats			
Location	**#Courses**	**#Regs**	**Income**
Orlando	20	670	$156,687
Chicago	20	532	$112,736
Atlanta	20	734	$147,445
Vegas	20	491	$100,966
Chicago	0	0	$0
Orlando	21	1,141	$230,081

The combined total for ALI and bookstores revenue is estimated at $228,644.

OPEN SESSION – ADDRESSES TO THE BOARD OF DIRECTORS

Mr. Knight opened the floor for members and guests to address the BOD. Below is a summary of those comments:

Jim Early, Edison Electric Institute – Expressed thanks to staff for assistance in 90.1 meetings. Appreciate the continued support of Society and staff.

COUNCIL REPORTS

MEMBERS COUNCIL

Mr. McQuade reported on behalf of the council. The full report was shown on screen and was attached to the agenda.

Mr. McQuade moved that

1. Members Council recommends to the Board of Directors that a new Presidential Initiative Coordinator position be added as a permanent member of the YEA Committee roster.

Mr. McQuade reported that the President-Elect Advisory Committees for the last three years have asked for additional responsibilities be taken on by YEA to support the selection of and awards of funds as an initiative to support the respective year's Presidential Theme. The first challenge fund was implemented through YEA (2023-24 Decarbonization); it's success led to its continuation with the next year's challenge (2024-25 DEI/Workforce Development). PEAC and TRAC have expressed a desire to continue the program to support future presidential themes.

To implement the Challenge program, YEA used a one-year appointed consultant that has now been renewed two years in a row. YEA would prefer to eliminate the consultant position and make this a permanent position by adding to the voting committee membership the Presidential Initiative Coordinator, a member dedicated to the Presidential Initiative Challenge tasks. This would result in a change to the Rules of the Board Section 2.430.002.1 which SRC has reviewed and approved.

MOTIONN 1 PASSED (Voice Vote, 1 Abstention, CNV).

Mr. McQuade moved that

2. Members Council recommends to the Board of Directors to allow Affiliate Members to hold an officer and/or chair position at the Chapter level, with the exception of the President, President-Elect, and Treasurer.

Mr. McQuade reported that Affiliate Members receive reduced membership dues for the first three years of membership but do not have voting privileges, an annual complimentary benefit selection, or the ability to hold office at the Chapter, Region, and Society levels.

The proposed motion will eliminate the need for Affiliate Members to upgrade their membership grade to hold office at the chapter level. The potential financial loss with this change is approximately $13,500/year, based on the assumption that 75 second-year Affiliate Members will not upgrade each year. We cannot calculate the profit loss of those that have offered to volunteer but have been turned away and ultimately cancelled their membership. We cannot calculate the profit loss of those that have offered to volunteer but have been turned away and the impacts of having an empty chair position. This

would result in a change to the Rules of the Board Sections 2.103.003.6, Paragraph E and 2.103.003.7, Paragraph C and D which SRC has reviewed and approved.

Ms. Schopplein stated that SRC suggested that Members Council investigate the impact that this change would have on Chapter Delegates and Alternates.

Mr. Sanders spoke in favor of the motion. He stated that Affiliate Membership is a great idea in concept but has caused issues at the chapter and regional level.

MOTION 2 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. McQuade said that he would follow up on Ms. Schopplein's comment.

Mr. McQuade moved that

3. Members Council recommends to the Board of Directors to remove the age restriction for Affiliate Membership.

Mr. McQuade reported that adding an age limit to Affiliate Membership reduces the potential of adding new members. By allowing someone to become an Affiliate Member regardless of their age, they can get involved with ASHRAE without committing to becoming a Full Member initially but potentially transitioning to a Full Member.

The Membership Promotion Committee voted to recommend defeating the motion (MP Vote: 0-14-0, CNV) with the reason that the MP Committee felt that the age restriction was appropriate as the goal of the program is to assist young professionals that were not ASHRAE Student Members and not allowing a tiered reduced membership over three years for all members.

Members Council, however, decided to approve the motion from the Central Pakistan Chapter citing that removing the barrier of age would encourage more new members to join regardless of their age and work their way up to paying the full dues payment rate. This would result in a change to the Rules of the Board Section 2.103.003.7, Paragraph A which SRC has reviewed and approved.

The floor was opened for discussion. A summary of that discussion is below:

Spoke against the motion. Disagree that there would be a Society-wide increase. With the MMAH motion pending, suggest that the rule remain as is and report that wider sweeping changes are coming soon.

Why was the motion defeated by MP? Mr. Holcomb reported that there would have been a potential loss of $530 per member per year and MP felt it was not in Society's best interest.

Spoke against the motion. Would like to see the MMAH recommendations perceived as an improvement. If this motion passes, the MMAH recommendations may not be perceived that way.

How can staff impact be none when there are tasks assigned to staff? Mr. McQuade reported that there would be no ongoing staff impact.

Spoke against the motion. Removing Affiliate could impact the number of people who would otherwise become full Members.

If the MMAH recommendations do not pass, would that change the perspectives of BOD members that are not in favor?

When would this go into effect? How many Affiliate Members are there? Ms. Seymour reported that if approved, it would go into effect next Society Year. She added that there are currently 1,375 Affiliates with about 110 in developing economies.

Mr. McQuade reported that the earliest MMAH recommendations would not go into effect for about two years and this motion would go into effect next Society Year.

Retention data for Affiliate Members was requested. The number of members over 35 was requested. Ms. Seymour stated that the requested data was not available but could be provided at a later date.

MOTION 3 FAILED (1:28:1, CNV).
Mr. Yashar abstained.

Mr. McQuade reviewed information items from the report, and they were shown on screen.

There was discussion of the Bangladesh and Sri Lankan Chapters being reassigned from Region XV to RAL, effective July 1, 2025.

Mr. Bertuch asked for the reason for the change.

Mr. Anbari reported that both chapters wanted to be associated with RAL. He stated that political issues make travel difficult and RAL has areas where those members do business. He reported that there was lots of discussion at Members Council.

Mr. Mittal reported that members from those chapters wanted to move to RAL. It was requested that they wait one to two years, but the council wanted to respect the wishes of the members.

Mr. McQuade reported that the Region Operations Subcommittee asked that each region perform a health assessment. Asking that a plan be developed for struggling chapters or that they be changed to section or dissolved. DRC assistance was requested with this exercise. He stressed that this item be addressed this Society Year.

Mr. Wright (Buzz) suggested that it could be helpful to add the number of years a chapter has been in existence to the tracker so that fact isn't ignored.

Mr. Craddock stated that there were chapters in his region that he would consider struggling but that were not listed. Is there a standard for where chapters should be?

Mr. McQuade responded that each chapter may have its own set of circumstances. This request is one step in the number of metrics that Society should be looking at. There does not seem to currently be any recourse when a chapter is underperforming. This can be addressed for the remainder of this Society Year and into the next if Ms. Maston determines it to be a priority.

Mr. Peach expressed his opinion that there had been some actionable work that was not captured in the report.

Mr. Bertuch asked how a chapter could be added to the list.

Ms. Timberman reported that she chaired the subcommittee that produced the report. She advised that chapters to be added could be sent to her. She reported that RMCRs were asked to work with DRCs to provide this data. RMCRs have also been asked to provide an update at the Annual Conference.

She reported that Members Council cannot, per the MCO, make recommendations; the council can only compiled and share the data. DRCs have the authority to make those recommendations and better understand how to assist struggling chapters.

She reported that the subcommittee was taking this task very seriously and were working to establish processes. She encouraged feedback and comments from DRCs to make the tracking tool as accurate and helpful as possible.

Mr. Knight thanked Mr. McQuade and Members Council for their hard work all year long.

PUBLISHING AND EDUCATION COUNCIL

Mr. Sekhar reported on behalf of the council. The full report was attached to the agenda.

Mr. Sekhar moved that

4. The ASHRAE Board of Directors (BOD) approve changes to the Publications Committee's Rules of the Board (ROB) as shown in ATTACHMENT A.

Mr. Sekhar reported that the proposed changes reflect changes to the ROB based on feedback from PEC and guidance from SRC. PEC approved the recommended changes 9-0-0, CNV.

Ms. Schopplein reported that the proposed changes were reviewed by a few members of SRC, not the entire committee. There was consensus from those members that the changes be accepted.

Mr. Ellis, ExO to the Publications Committee, reported that there was an update to the ROB last year and there was a feeling that there was extraneous information. The goal of the proposed changes is to streamline and bring the ROB in line with other committees. Some of the deleted information was moved into the committee's MOP.

MOTION 4 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. Sekhar reviewed information items from the council report and they were shown on screen.

TECHNOLOGY COUNCIL

Mr. Conlan reported on behalf of the council. The full report was attached to the agenda.

Mr. Conlan proposed that motions 1 through 5 from the report be considered as a consent motion. Mr. Peach requested that motion 3 be removed from the consent motion for further discussion.

Mr. Conlan moved that

5. The following be approved as a consent agenda:

- Technology Council recommends to the Board of Directors that the Rules of the Board 1.201.004, *Policy and Definitions of ASHRAE Standards and Related Documents*, be revised as shown below:

  1.201.004 Policy and Definitions of ASHRAE Standards and Related Documents

  1.201.004.2 Place emphasis on development of documents that establish ASHRAE as the leader in HVAC&R technology, providing state-of-the-art best practice guidance that advances the arts and sciences of our industry. ~~Such guidelines and state of the art standards should normally be written in informative language.~~

- Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.003.3, *Operation*, be revised as shown below:

  2.425.003.3

  A. All ASHRAE standards intended for ANSI designation shall be submitted for ANSI approval as American National Standards.

- Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.004.2, *Policy on Standards Committee Document Development*, be approved as shown below:

  2.425.004.2
  Consensus standards define minimum values or acceptable performance, whereas other documents, such as guidelines or design guides, offer practical guidance, best practices, or encourage enhanced performance.

- Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.008, *Strategic Plan*, be approved as shown below:

  2.425.008 Strategic Plan
  This committee shall ~~develop procedures for recommending updates to the strategic plan on a continuous basis. As a minimum the committee shall~~ submit a report to the council prior to the Annual Meeting that~~.~~ ~~The report~~ includes the ~~current~~ status of each activity which supports the fulfillment of the committee's assignments under the strategic plan. The committee shall report to the council all recommendations for changes to the strategic plan as provided by the committee's constituents prior to the Annual Meeting.

Mr. Conlan reported that the proposed ROB changes are clean up items.

MOTION 5 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. Conlan moved that

6. Technology Council recommends to the Board of Directors that the Rules of the Board 2.425.003.6, *Operation*, be approved as shown below:

2.425.003.6

D. Formation of all new standard project committees and titles, purposes and scopes, shall be approved by the ~~Board of Directors~~ Technology Council or its designee before the project committees take action.

Mr. Conlan reported that the proposed change represents a change to the reporting body.

Ms. Reiniche reported that this change was put in PASA and this change would make it consistent with ANSI. She stated that the proposed change would streamline and move approvals to the council.

Mr. Littleton reported that when Tech Council approves a new TPS for a new standard, that approval will be reported to the BOD as an information item.

MOTION 6 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. Conlan moved that

7. Technology Council recommends to the Board of Directors that all ASHRAE Regions with Chapters outside United States and Canada appoint a liaison (Regional position) who will work closely with the GTIC to help in interaction with the ASHRAE Chapters in their Region and help promote exchange of ASHRAE technical resources to meet its objectives.

Mr. Conlan reported that the recommendation aims to mimic DEI grassroots positions to help GTIC cover more ground. Taking this on by the CTTC Chair would be a burden. If approved, a written description would be developed to help the chapters and regions pick the best people.

Mr. Littleton spoke in favor of the motion. Would the proposed liaisons not be members of GTIC and only coordinate with GTIC?

Mr. Conlan stated that was correct. He added that the liaison would be a regional position and would gather information from GTIC and share it with the chapters and regions.

It was asked why the liaison couldn't also be the GTIC Chair. Mr. Conlan responded that could make sense, but appointments would be at DRC discretion.

Where will these liaisons be identified? Mr. Conlan responded that they would be listed on the regional CIQ and appointed by the DRC.

No fiscal impact? Won't the liaisons need to travel to meetings? Mr. Conlan responded that the proposed liaisons would not be GTIC society liaison; instead, it would be an individual that GTIC can connect with and send information to. In most regions, the appointed chairs' travel would be covered by the region and not Society.

Are there suggested terms of service? Mr. Conlan responded that the terms of service would be at the DRC's discretion.

Would this be at the chapter and regional levels? Mr. Conlan responded that the recommendation is for a regional position.

MOTION 7 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. Conlan moved that

8. Tech Council recommends that the Board of Directors approve the revised *Indoor Carbon Dioxide* position document (PD) as shown in ATTACHMENT B.

MOTION 8 PASSED (Voice Vote, 2 Abstentions, CNV).
Mr. Yashar and Mr. Sekhar abstained.

Mr. Conlan reviewed information items from the report, and they were shown on screen.

He thanked Standards Committee and Mr. Fick for the work done. He stated that it looks as though Society is moving towards more harmonization in terms of IAQ and Society documents.

COMMITTEE REPORTS

EXECUTIVE COMMITTEE – WEDNESDAY, FEBRUARY 12, 2025

Mr. Knight reported that there were no recommendations for the BOD's consideration. He reviewed information from the report. The full report was attached to the agenda and shown on screen.

SOCIETY RULES COMMITTEE

Mr. Sekhar reported that SRC would not be making motion 1 from their report as there were some inconsistencies that needed to be sorted out.

Mr. Sekhar moved that

9. The Society Rules Committee recommends to the Board of Directors that the below changes to ROB Section 2.415.003.1, *Nominating General Requirements* be approved as presented:

2.415 NOMINATING COMMITTEE

…

2.415.003.1 General Requirements

D. All nominees for Director shall be apprised fully of their duties and responsibilities, and of the time and expense involved in the execution thereof. (62-11-03-26)

E. The Nominating Committee shall require a self-certification letter annually from all society officer nominees. (21-02-04-01/15-07-01-19)

F. Executive session protocols shall be considered enforced for any candidate consideration discussions between current nominating committee members during, or after, formal

Nominating Committee meetings. Such discussions held at the discretion of the members shall be done in a confidential manner and not enjoin any other non-members in the discussion.

Mr. Sekhar reported that confidentiality in the Nominating process is vital to the process of providing a slate of qualified officers and should be noted in the Nominating ROB. Currently, per the Nominating Committee MOP, Nominating Committee members are allowed to have executive session discussions as outlined above, but that guidance is not currently in the ROB.

As long as members are in a private place and only current members or alternates or the Nominating Committee, who were present during executive session, are in attendance, discussion of executive session items is allowed.

This recommendation would update the ROB to mirror guidance that is already included in the Nominating MOP.

MOTION 9 PASSED (Voice Vote, 1 Abstention, CNV).
Mr. Yashar abstained.

Mr. Phillips reviewed information items from the report, and they were shown on screen.

Mr. Knight thanked Mr. Phillips and SRC for keeping all the rule straight each year.

AUDIT COMMITTEE

Mr. Sanders reported that there were no recommendations for the BOD's consideration. He reviewed information items from the report. The full report was attached to the agenda and shown on screen.

Mr. Knight thanked Mr. Sanders and the committee for the report and their great work.

FINANCE COMMITTEE

Ms. Maston reported on behalf the committee. The full report was attached to the agenda and shown on screen.

She reviewed pledged endowments as well as fully funded endowments. The BOD applauded in recognition of member's generous support.

Clarification on the Setty announcement at the President's Lunch was requested. Ms. Pilot reported that the announcement was to recognize Mr. Setty for his combined contributions to Society surpassing $1,000,000.

Ms. Maston reviewed updates from the Scholarship's Trustees. She reported that $210,000 worth of scholarships were awarded this Society Year.

Mr. Littleton stated that scholarship applications had grown significantly, which is great news.

It was asked if Chapter Leadership Academy funding was still being provided. Ms. Pilot reported that it was a one-time funding request but could be considered again. Ms. Seymour reported that a new request would be sent.

Mr. McQuade acknowledged the staff and the Development team for the step change in the number and amounts of gifts that Society has received. He led an acknowledgement and round of applause for the Development Committee and Foundation.

Mr. Knight thanked guests for their attendance and interest in the work of the BOD.

EXECUTIVE SESSION

Executive session was called at 3:41 pm.

Open session reconvened at 4:09 pm.

UPCOMING MEETINGS

Mr. Knight reviewed upcoming BOD conference calls. He reminded the BOD of the BOD dinner that evening.

ADJOURNMENT

The meeting adjourned at 4:14 pm.

Jeff Littleton

Jeff H. Littleton, Secretary

ATTACHMENTS:

A. Publications Committee Proposed ROB Edits
B. Proposed Revised *Indoor Carbon Dioxide* PD

Changes to Publications Committee ROB

2.419 PUBLICATIONS COMMITTEE

2.419.001 SCOPE AND PURPOSE

This committee identifies the technical information needs of the HVAC&R industry not met through the ASHRAE Handbook series, ASHRAE's research journal, standards, guidelines, or user's manuals and oversees editorial policies and delivery of products to the marketplace. This committee also determines the best paper published in the volume year of *ASHRAE Journal* preceding the ASHRAE Winter Conference.

This committee shall report to the Publishing and Education Council.

2.419.002 MEMBERSHIP

2.419.002.1 Composition

The members of this committee are as follows:

A. Twelve (12) voting members, including a chair and a vice chair. (16-06-29-20)
B. Non-voting members include a Board ex officio member and coordinating officer.

2.419.002.2 Qualifications

A. All members of the committee shall hold the grade of Associate Member or higher in the Society.
B. Members should have an awareness of the current technical information needs of various segments of the HVAC&R industry.
C. Membership should include broad representation from the HVAC&R industry including the academic, design, construction, facility operations and manufacturing communities.
D. At least three members should have recent experience with the production or writing of technical publications or periodicals.

2.419.002.3 Term of Service

The term of service for the chair and vice chair is intended to be one (1) year. The term of service for other voting members is intended to be three (3) years.

2.419.003 OPERATION

2.419.003.1 General Requirements

~~A.~~ This committee shall oversee the editorial policies of ASHRAE's Special Publications, *ASHRAE Transactions* and other conference proceedings, *ASHRAE Journal*, and ASHRAE's electronic newsletters.
~~The committee shall be subject to these conditions:~~
~~2. The data recommended for publication shall tend toward the professional education of the individual engineer;~~
~~3. Such data shall be free from commercial bias;~~

4.1. Such data shall tend to advance for the public benefit the arts and sciences relating to heating, refrigeration, air conditioning, and ventilation and the allied arts and sciences.
(67-06-25-08/82-06-30-25/86-06-22-18M)

B. ASHRAE This committee shall oversee produce Special Publications that shall be defined as all technical publications produced by ASHRAE in print and machine-readable format in print format (except for the ASHRAE Handbook series; standards, guidelines, and user's manuals; and ASHRAE's research journal, and ASHRAE's magazines, and newsletters), such asincluding books (including books resulting from ASHRAE Research Projects and Special Projects), charts, and tools, as well as all technical publications in machine-readable format, such as audio and visual presentations, software, databases, apps, and online resources. These special publications may be generated from proposals submitted directly to Publications Committee or from accepted Publication Topic Acceptance Requests (PTARs), which Publications Committee reviews before providing recommendations to Research Administration Committee (RAC) for the final vote regarding funding. This committee shall also communicate with the cognizant TCs of existing ASHRAE publications to help staff determine whether older publications are up to date as is, need to be revised, or need to be removed from sale.

C. The objective of *ASHRAE Transactions* shall be to serve as the archival publication of unsolicited research papers and Society-sponsored research and discussions in HVAC&R technical areas presented at the ASHRAE Annual and Winter Conferences as well as of Society business such as council and committee membership and award recognition. The objective of proceedings of ASHRAE-sponsored conferences and ASHRAE-cosponsored conferences shall be to serve as the archival publications of the unsolicited research papers presented at these conferences.

C. This committee shall advise about the magazineThe objective of *ASHRAE Journal*, which shall be to lead in the communication of heating, ventilating, air-conditioning and refrigeration information to and from the profession, industry, and related interests. (ROB 520-144-007) and which shall include e. Editorial and advertising content of *ASHRAE Journal* shall be directed toward the professional education of persons engaged in industries related to heating, ventilating, air conditioning, and refrigeration (86-06-22-18L).

D. This committee shall determine the annual winner of the Journal Paper Award.

E. The objective of ASHRAE's electronic newsletters shall be to communicate news to various audiences. *Insights*, distributed to members only, includes news of members, chapters, regions, Society committees, and International Associates. (ROB 520-144-007, 86-06-22-18L) *ASHRAE Journal Newsletter*, distributed to members only, connects news of industry trends with articles from *ASHRAE Journal*'s archive of peer-reviewed content. *ASHRAE HVAC&R Industry News* curates the latest trends and announcements from the industry to a large readership of members and non-members. *HPB Newsletter* combines online HPB articles and *ASHRAE Journal* articles with links to external articles related to energy efficiency, resiliency and sustainability for a diverse audience of ASHRAE engineers, architects, facilities managers and building owners.

2.419.004 STRATEGIC PLAN (09-06-21-12C)

This committee shall develop procedures for recommending updates to the strategic plan on a continuous basis. As a minimum the committee shall submit a report to the council prior to the Annual Meeting. The report includes the current status of each activity which supports the fulfillment of the committee's assignments under the strategic plan. The committee shall report to the council all recommendations for changes to the strategic plan as provided by the committee's constituents prior to the Annual Meeting.

ASHRAE Position Document on

Indoor Carbon Dioxide

Approved by the ASHRAE Board of Directors February 2, 2022

Expires February 2, 2025

ASHRAE is a global professional society of over 55,000 members, committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields (HVAC&R). ASHRAE position documents are approved by the Board of Directors and express the views of the Society on specific issues. These documents provide objective, authoritative background information to persons interested in issues within ASHRAE's expertise, particularly in areas where such information will be helpful in drafting sound public policy. The documents also clarify ASHRAE's position for its members and building professionals.

Indoor Carbon Dioxide is a Public Interest Issue

Indoor carbon dioxide (CO_2) has been considered in the context of building ventilation and indoor air quality (IAQ) for centuries. Historically, these discussions have focused on the use of CO_2 to evaluate ventilation rates, how CO_2 concentrations relate to occupant perceptions of IAQ, and the use of CO_2 as a general indicator of IAQ. While these topics have been studied for decades, incorrect application and misinterpretation of CO_2 concentration as an indicator of IAQ and ventilation is common in the HVAC industry, research community, and the public. Despite many efforts to address these concerns in standards, guidance documents, technical publications, and conference presentations, significant misunderstanding of the application and meaning of indoor CO_2 remains.

More recent research and discussions have considered the impacts of pure CO_2 on humans, in particular, adverse effects on cognitive performance, at commonly observed indoor concentrations. Indoor CO_2 monitoring has also been promoted as a ventilation indicator in the context of managing the risks of airborne disease transmission. Additionally, concerns have long existed regarding the accuracy of indoor CO_2 concentration measurements, which are now more common due to the availability and more widespread application of less expensive sensors. Given all of the above issues, as well as increasing calls to monitor CO_2 in buildings, ASHRAE recognizes the need to clarify the use of indoor CO_2 measurements as a tool to monitor and help improve IAQ and building ventilation.

Why ASHRAE Takes Positions on Indoor Carbon Dioxide

ASHRAE consensus standards, design guides and other resources provide the technical foundation for international building practices and codes that support the essential need to provide indoor environments that support occupant health, comfort and productivity in a cost effective and energy

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

efficient manner. The design, construction and operation of buildings' systems can support this goal through the use of these ASHRAE resources.

The longstanding application of indoor CO_2 to issues of building ventilation and IAQ has already been described. ASHRAE takes positions on this topic because many applications reflect a deficient technical understanding of the relationship between indoor CO_2 concentrations, ventilation, and IAQ. Some these applications are technically flawed, leading to misinterpretations of the significance of indoor CO_2. In response to these misinterpretations, this position document attempts to clarify the role of indoor CO_2 in the context of building ventilation and IAQ management based on ASHRAE's long involvement with those topics as well as the interests of its members and stakeholders.

ASHRAE Takes The Positions That:

1. Indoor CO_2 concentrations are not overall indicators of IAQ, but they can be a useful tool if users understand how they relate to IAQ and the important limitations of their use.
2. Differences between indoor and outdoor CO_2 concentrations can be used to evaluate outdoor ventilation rates and air distribution using established tracer gas measurement methods, but accurate ventilation measurements require the validity of several assumptions and accurate input values.
3. Existing evidence for direct impacts of CO_2 on health, well-being, learning outcomes, sleep pattern and work performance at commonly observed indoor concentrations is inconsistent. This evidence does not currently justify changes to ventilation and IAQ standards, regulations, or guidelines.
4. The use of indoor CO_2 measurements to assess and control the risk of airborne disease transmission must account for the definition of acceptable risk, the type of space and its occupancy, spatial and temporal variations, ventilation and air distribution, differences in CO_2 and infectious aerosol emissions, and the impact of these factors on the fate and transport of both CO_2 and infectious aerosols.
5. Sensor performance, location, and calibration are all critical for drawing meaningful inferences from measured indoor CO2 concentrations.
6. Air-cleaning technologies that remove only CO_2 may not improve overall IAQ and can interfere with systems using CO_2 for ventilation control or IAQ monitoring.

ASHRAE Recommends That:

Research be conducted on the following topics:

1. Indoor CO_2 exposure as a modifier of human responses to factors such as the thermal environment and airborne contaminants

2. The development of IAQ metrics that cover the wide range of indoor contaminants and sources that impact building occupants

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

3. Health, comfort, productivity, learning and sleep impacts of indoor CO_2 in concentration ranges typical of non-industrial indoor environments in both laboratory and field settings covering a diverse range of subjects, including variations in age, gender, and health status
4. Physiological impacts of exposure to CO_2 in concentration ranges relevant to indoor environments, such as changes in blood chemistry and respiration, including those associated with increasing outdoor CO_2 concentrations
5. The significance of indoor CO_2 concentration as an indicator of ventilation and the risks of airborne infectious disease transmission
6. Indoor CO_2 concentration measurement, including sensor performance and sensor locations for different applications and the performance and application of consumer grade CO_2 sensors
7. The use of occupant-generated CO_2 as a tracer gas to estimate building ventilation rates, including approaches that capture transient effects and account for multiple-space ventilation systems and different air distribution approaches
8. Strategies for demand-controlled ventilation (DCV) using CO_2 and other indicators of occupancy that overcome limitations of current approaches and control contaminants that are not linked to occupancy
9. Indoor CO_2 concentrations, ventilation rates, and occupancy in different building types in different countries to establish benchmark data and better understand the impacts of new building and system designs, tighter construction, advanced operation and control strategies, and other changes in the building stock

The following activities be pursued:

10. Development of guidance and standards on indoor CO_2 concentration measurement and sensor selection, especially for DCV applications
11. Development of educational programs, conference sessions and workshops, and guidance documents to help practitioners and researchers understand the application of indoor CO_2 concentrations as an indicator of ventilation and IAQ
12. Development of guidance on HVAC equipment and controls using CO_2 monitoring
13. Development of guidance on the use of CO_2 as a tracer gas for measuring building ventilation rates and air distribution

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

APPENDIX A – BACKGROUND

This appendix contains a detailed and thoroughly referenced discussion that supports the positions and recommendations in this document. Specifically, it presents the following material: the history of the role of indoor CO_2 concentrations in the context of building ventilation and IAQ, health and cognitive impacts of exposure to CO_2, existing standards and regulations for indoor CO_2 concentrations, CO_2 as an indicator of IAQ and ventilation, use of CO_2 as a tracer gas for estimating ventilation rates, increases in outdoor CO_2 concentrations, air cleaning directed at CO_2 removal alone, and CO_2 as an indicator of the risk of airborne disease transmission.

A.1 - History of CO_2 in Relation to Building Ventilation and IAQ

The overview of early CO_2 research discussed in this paragraph is provided by Wargocki (2021). Carbon dioxide has been discussed in the context of building ventilation since the seventeenth century when Mayow proposed that igneo-aerial particles produced by candles cause the demise of animals. In the eighteenth century, Lavoisier attributed the effects of these particles to CO_2. At that time, CO_2 rather than a lack of oxygen was considered to be a cause of physiological effects attributed to bad air and an indicator of whether the air was stale or fresh. In the nineteenth century, Max Josef von Pettenkofer stated that it was not CO_2 but the presence of organic material from human skin and lungs that caused the negative effects attributed to poor ventilation. He and Saeltzer proposed that CO_2 should not be considered as a cause of discomfort but rather as a surrogate for vitiated air and an indicator of deleterious airborne substances of unknown origin. Pettenkofer proposed 1000 ppm_v of CO_2 as a marker of inadequate ventilation indoors and 700 ppm_v for bedrooms. In the early twentieth century, studies by Billings, Hermans, Flugge, Hill and others showed that warmth combined with smells in a crowded room were a source of discomfort in poorly ventilated rooms. Experiments with CO_2 increasing to 3% or 4% and oxygen falling to 17% did not show negative effects except for deepened breath and the need for cooling. The work of Lemberg and later Yaglou showed that perception of human body odor could be used as a criterion for ventilation rates. Perceived odor intensity was used as a criterion for ventilation rate requirements of about 7.5 to 10 L/s (15 to 20 cfm) per person (Persily 2015). CO_2 was, again, not considered a pollutant but rather a marker of body odor perception, since humans emit both CO_2 and bioeffluents at rates related to their metabolism. Studies in the latter part of the twentieth century by Fanger, Cain, and Iwashita, in which acceptability of perceived air quality was used as the criterion for ventilation requirements, confirmed the results of Yaglou and Lemberg. This research on body odor perception was used to develop the ventilation requirements in ASHRAE and European Committee for Standardization (CEN) standards. The 1989 edition of ASHRAE's ventilation standard, Standard 62 (subsequently Standard 62.1), had a CO_2 limit of 1000 ppm_v, but this was removed from subsequent editions due to its common misinterpretation. (ASHRAE Standard 62.1 now contains CO_2 concentrations to be used as setpoints for demand control ventilation as discussed in A.4.) More recent research and discussions have focused on effects of pure CO_2 at the levels typically occurring indoors including impacts on cognitive performance, physiological responses and sleep quality. In the context of the COVID-19 pandemic, CO_2 has also been increased discussed as a means of estimating the risk from infectious diseases as well as the activity (survivability) of airborne virus.

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

A.2 - Health and Cognitive Effects of CO_2 Exposure

This section summarizes the evidence for health and cognitive impacts of CO_2 exposure, with health focused on impacts other than airborne infection, which is discussed in A.8. Carbon dioxide is considered nontoxic at concentrations up to 5000 ppm_v, which is the U.S. federal standard (Permissible Exposure Level) for workplaces set by the Occupational Safety and Health Administration (OSHA) as noted in the later section on existing standards and regulations. Guidelines for the International Space Station and U.S. submarines currently suggest that CO_2 concentrations be maintained at 4000 to 5000 ppm_v to reduce the incidence of headaches (James and Zalesak 2013; Scully et al. 2019). Indoor concentrations greater than 1000 ppm_v have been associated with increases in self-reported, nonspecific symptoms commonly referred to as *sick building syndrome (SBS) symptoms*, as well as decreased performance on office work and schoolwork, as discussed in the following paragraph. These observations were not controlled for other contaminants or environmental parameters; therefore, elevated CO_2 concentrations likely served as indicators of inadequate ventilation that increases the concentration of all contaminants with indoor sources (Persily 2015; Lowther et al. 2021).

Several groups have explored the effects of acute exposure (duration from 2 to 8 h) to pure CO_2 at concentrations between 600 and 5000 ppm_v, as summarized by Fisk et al. (2019), Du et al. (2020), and Lowther et al. (2021). Note that building occupants are never exposure to pure CO_2 but rather to a complex mixture of airborne contaminants, which includes CO_2, human bioeffluents and many other gases and particles. Six studies reported an association between CO_2 and decreased cognitive performance at concentrations in the range of 1000 ppm_v (Satish et al. 2012; Allen et al. 2016, 2018; Kajtar and Herczeg 2012; Lee et al. 2022; Lu et al. 2024), and one was equivocal (Scully et al. 2019). While three of these studies demonstrated concentration-dependent impairment, an indicator of a causal effect, other studies did not show any cognitive effects (Zhang et al. 2016a, 2016b). These inconsistencies require further investigation, including study of the mechanisms involved.

Regarding these mechanisms, studies with mice show inflammatory changes consistent with neutrophil (a type of white blood cell) activation in the blood at 2000 to 4000 ppm_v and leakage of fluid from blood vessels into brain tissue at 2000 ppm_v (Thom et al. 2017a). Further confirmation of these inflammatory changes was found in in-vitro and controlled human exposure at the same concentrations (Thom et al., 2017b; Lu et al. 2024). These findings support the phenomenon of brain toxicity from pure CO_2 and are mechanistically consistent with reports of cognitive changes observed in the human experiments at commonly observed indoor concentrations. Further research on these mechanisms and human response to CO_2 is important due to the prevalence of indoor concentrations in excess of 1000 ppm_v as well as animal work that provides direction for investigation of mechanisms for declines in cognitive function (Jacobson et al. 2019). This research needs to address the impacts of stress experienced by the subjects and exposure to other contaminants (e.g., bioeffluents) in addition to CO_2.

Studies on CO_2 in connection with the risk of infection are discussed in A.8 and therefore omitted here.

A.3 - Existing Standards and Regulations for Indoor CO_2 Concentrations

Many countries have proposed mandatory or suggested guideline values for indoor CO_2 in non-industrial spaces, absolute or differential with respect to outdoor concentration. It should be noted

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

that the rationales supporting these guideline values are not necessarily provided in the reference documents (Mendell et al., 2024).

CO_2 guideline values proposed in the context of the COVID-19 pandemic are not included in this discussion. Pandemic-motivated values are discussed in the later section on airborne infection risk transmission.

Indoor CO_2 limits are listed in a database developed by the International Society for Indoor Air Quality and Climate, ISIAQ (https://iegguidelines.org/). Some of these values are set for all occupied buildings, while others make a distinction between residential and nonresidential buildings. These limits tend to be on the order of 1000 ppm_v but range as high as about 1500 ppm_v. They are generally intended for the management of generic IAQ concerns and SBS symptoms, with CO_2 being used as an indicator of ventilation. Of particular note is the 1000 ppm_v limit in Japan that was issued in 1970; thousands of buildings are tested every year to determine if they comply with the Building Sanitation Maintenance Law.

For workplaces, the United States Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) have established a time- weighted average limit value of 5000 ppm_v for airborne exposure in any 8-hour work shift during a 40-hour workweek and 30,000 ppm_v as a short-term exposure limit, i.e., a 15-minute time-weighted average that should not be exceeded at any time during a workday (NIOSH 1976; OSHA 2017). Note that the OSHA limit is regulatory while the NIOSH limit is voluntary.

Despite many statements to the contrary, ANSI/ASHRAE Standard 62.1 (ASHRAE 2022b) does not provide a limit value for indoor CO_2. Misunderstanding of information in previous editions of the standard continue to lead many to incorrectly attribute a 1000 ppm_v limit to ASHRAE. However, a 2023 addendum to the standard added "Maximum CO_2 Above Ambient" differentials for use when applying DCV under the prescriptive Ventilation Rate Procedure, as discussed further in A.4. These differentials are set points based on hypothetical maximum occupancy and do not reflect the detailed control sequences required to implement DCV, which are often more complex than on/off thresholds, particularly when occupancy varies and in multiple zone and recirculating systems. CEN 16798-1 (2019) provides four categories of indoor environmental quality that include CO_2 concentrations above outdoors, noting that these values serve as indicators of outdoor air ventilation rates per person: Category I, 550 ppm_v; Category II, 800 ppm_v; and Category III and IV, 1350 ppm_v. These categories correspond to the expectations of occupants, with normal expectations corresponding to Category II.

Carbon dioxide is also addressed in green building certification programs. Reviews of the major green building certifications developed worldwide and the indicators they use to assess indoor environment quality showed that CO_2 is one of the most commonly specified IAQ metrics in these certifications (Wei et al. 2015, 2020). However, the reference values used to assess CO_2 concentrations are not uniform, varying from 530 to 1500 ppm_v (Wei et al. 2015).

A.4 – CO_2 as an Indicator of IAQ and Ventilation

As previously noted in the history section (A.1), indoor CO_2 has been prominent in discussions of ventilation and IAQ for centuries. While CO_2 concentrations are related to the perception of human bioeffluents and the level of acceptance of their odors, they are not a good overall metric of IAQ, as many important contaminant sources do not depend on the number of occupants in a space. For example, contaminants emitted by building materials and those that enter from outdoors are not

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

correlated with CO_2 concentrations. Furthermore, many important contaminants are removed from indoor air by processes (e.g., deposition of particles) and engineering controls (e.g., inactivation of viral aerosols by germicidal ultraviolet light) that do not affect CO_2 concentration. Nevertheless, if outdoor air ventilation rates are reduced in an occupied building, concentrations of CO_2 will increase along with the concentrations of other contaminants generated indoors. This fact likely explains observed associations of increased CO_2 concentrations with higher SBS symptom rates, absenteeism, and other effects (Apte et al. 2000; Shendell et al. 2004; Gaihre et al. 2014; Fisk 2017).

An indoor CO_2 concentration below 1000 ppm_v has long been considered an indicator of acceptable IAQ, but this concentration is at best an indicator of outdoor air ventilation rate per person. That relationship is based on the use of CO_2 as a tracer gas as described in the next section (A.5) and is associated with an outdoor air ventilation rate of about 8 L/s (16 cfm) per person. This value of 1000 ppm_v has been used for decades without an understanding of its basis, which is its link to the perception of human body odor by building occupants. This misunderstanding of the significance of 1000 ppm_v has resulted in many confusing and erroneous conclusions about IAQ and ventilation in buildings. Use of CO_2 as an indicator of outdoor air ventilation must reflect the fact that outdoor air ventilation requirements are a function of space type and occupant characteristics (e.g., age and body mass), activity levels, and density. Therefore, a single CO_2 concentration does not apply to all space types and occupancies for the purposes of assessing the ventilation rate. Also, CO_2 concentrations can vary significantly within a building or space based on the details of how ventilation and air distribution are implemented.

Indoor CO_2 concentrations have long been used to control outdoor air intake rates, using a process referred to as *demand-controlled ventilation* (DCV) (Emmerich and Persily 1997; Lu et al. 2022). This control strategy reduces the energy use associated with overventilation during periods of low occupancy and helps to ensure that spaces are adequately ventilated based on their actual occupancy. DCV is in fact required by some energy efficiency standards such as ASHRAE/IES Standard 90.1 (ASHRAE 2022a), and CO_2 monitoring is one means of implementing DCV. Note that this control strategy can be more complex to implement in multiple-space ventilation systems when complying with the ventilation requirements in ASHRAE Standard 62.1 (ASHRAE 2022b) and the designer still must address contaminants not associated with occupancy levels. Recent research on DCV has led to control sequences for multiple-space systems (Lin and Lau 2015), which must also address the number and locations of sensors in different building zones and variations in CO_2 generation among zones and over time. As noted above, Standard 62.1 now contains CO_2 concentration values relative to outdoors for use as setpoints in applying DCV. These values are a function of space type, with and includes a statement that these values "are only for the purposes of implementing CO_2 DCV" and "are not intended to be and should not be used as indicators of IAQ." Note that with the increasing popularity of wearable devices, there is a possibility of new DCV applications with alternative sensing or technology to account for the variation of occupants.

A.5 - Use of Occupant-Generated CO_2 as a Tracer Gas

The use of indoor CO_2 concentration as an indicator of the adequacy of outdoor air ventilation rates is based on the application of CO_2 as a tracer gas. Tracer gas dilution methods for measuring outdoor air change rates have been used for decades and are well documented in existing standards (ASTM 2024; ISO 2017). Application of CO_2 to these methods simply takes advantage of a convenient tracer gas source, i.e., the building occupants. Tracer gas methods also exist to quantify air distribution and ventilation efficiency in spaces, and CO_2 can be used for these measurements as well. However, most

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

applications of CO_2 as a tracer gas assume the space in question is a single zone at a uniform tracer gas concentration.

As noted in ASTM D6245 (2024), there are two tracer gas methods for estimating outdoor air ventilation rates using CO_2: decay and steady state, both of which are best suited to single zones. Both methods are based on the following assumptions: the tracer gas concentration is uniform in the space being monitored, the outdoor CO_2 concentration is constant during the test (or monitored in real time), and the rate at which occupants generate CO_2 is known and constant for the steady-state method. People emit CO_2 at a rate based on their sex, age, body mass, and level of activity as described in ASTM D6245, and therefore information on the occupants is required to estimate these rates. When reporting the results of these tracer gas measurements, it is essential also to report the uncertainty of the results. ASTM D6245 discusses how to estimate these uncertainties. Because these are single-zone methods, they do not account for airflow and CO_2 transport between the zone of interest and other building zones. The measurement errors associated with using a single-zone approach in a space or building that is not a single zone at a uniform concentration is difficult to quantify, and these errors are often neglected in the application of these methods.

Peak CO_2 concentrations are commonly used to estimate ventilation rates per person using the constant injection tracer gas dilution method. For this approach to yield a valid result, the indoor concentration must be at steady state and the ventilation rate must be constant. Using a CO_2 concentration measured before achieving steady state will overestimate the ventilation rate. In a study of the uncertainty associated with CO_2 tracer gas measurements in an occupied space (Kabirikopaei and Lau 2020), the steady-state approach resulted in the lowest uncertainty and CO_2 sensor accuracy was the dominant factor in determining the overall uncertainty.

In recognition of the limitations of using peak CO_2 concentrations as a ventilation rate metric when steady-state conditions may not have been achieved, Persily (2022) describes an approach to estimate a space-specific CO_2 level that can serve as a metric of outdoor ventilation rates. This approach and the resulting concentrations are based on intended or expected ventilation rate, the number of occupants, the rate at which they generate CO_2, and the time that has transpired since the space was occupied. The calculation of CO_2 ventilation metric values is facilitated using a web-based tool developed by NIST called QICO2, which can be accessed at the following link: https://pages.nist.gov/CONTAM-apps/webapps/CO2Tool/#/.

A.6 - Increases in Outdoor CO_2 Concentrations

Outdoor CO_2 concentrations are relevant to consideration of indoor CO_2 for two reasons. First, when using DCV based on the absolute indoor CO_2 concentration, and not the indoor- outdoor difference, the outdoor air intake rate varies not only with occupancy but also with the outdoor air concentration. Second, if exposure to CO_2 is established to have health and cognitive impacts, then increases in outdoor concentrations will increase the prevalence of these impacts.

Global average CO_2 concentrations are determined by a complex interaction of sources, sinks, and driving forces. On a geological timescale, they have varied widely, but for hundreds of thousands of years, up until the early twentieth century, they were below 300 ppm_v, first exceeding 300 ppm_v in 1912 (EPA 2024). Over the ensuing half century, the average outdoor CO_2 concentration grew slowly, reaching 317 ppm_v in 1960 as measured at the Mauna Loa observatory in Hawaii. Since that time, atmospheric CO_2 concentrations have risen more rapidly, passing 400 ppm_v in 2013 and reaching 426 ppm_v in 2024. The annual growth rate has increased from less than 1 ppm_v per year in 1959 to

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

roughly 2.5 ppm_v per year (NOAA 2024). Superimposed on the trend of increasing outdoor CO_2 concentration are daily, seasonal, and annual variations. Daily variations are generally small, but a study of concentration over terrestrial ecosystems found an average seasonal peak-to-trough amplitude of 14.8 ppm_v, roughly three times the variation observed at the Mauna Loa observatory (Liu et al. 2015). Seasonal variations are attributable to cycles of biomass and photosynthetic activity of plants, with CO_2 being higher when plants are less active (Cleveland et al. 1983). Urban areas may experience much larger excursions of CO_2 above the global average due to lack of vegetation and the effects of internal combustion engine vehicles, as well as large vertical variations (Lietzke and Vogt 2013). Transient local concentrations may be hundreds of ppm_v above average in some locations, approaching or exceeding 600 ppm_v (Balling et al. 2001). Validated modeling indicates that elevated levels of ambient ozone and particulate matter may be associated with CO_2 domes (Jacobsen 2010). Local concentrations can also be below the average depending on season, time of day, and local vegetation (Liu et al. 2015). These variations in outdoor CO_2 make it important to measure outdoor concentrations when monitoring indoor CO_2.

A.7 - Air Cleaning Directed at CO_2 Removal Alone

While CO_2 can be useful as an indicator of ventilation and IAQ under limited circumstances, indoor CO_2 concentrations are not necessarily well correlated with other important indoor air pollutants such as viruses, mold, formaldehyde, carbon monoxide, asbestos, and airborne particles. Using air-cleaning technologies to reduce CO_2 for commonly observed indoor concentrations can result in an unjustified expectation that other indoor pollutants are not a concern.

It is important to distinguish between different air-cleaning technologies and how they impact different types of pollutants. The removal or conversion of CO_2 in the air can be achieved only by chemical reaction processes using sorption-type air cleaners (Hu et al. 2017). The removal of other important indoor contaminants requires other approaches, for example, airborne particle removal by mechanical filters. It is critical not to presume that air cleaning directed at CO_2 removal or conversion alone will remove indoor air contaminants that might be of concern. Also, when using CO_2-based DCV, the ventilation system will not operate as intended if using CO_2 removal al devices, since these ventilation controls assume that the measured indoor CO_2 concentration is proportional to human occupancy.

A.8 – CO_2 as an Indicator of Airborne Infection Risk Transmission

During the COVID-19 pandemic, recommendations have been made to use indoor CO_2 measurements as an indicator of the risk of airborne infection transmission (Peng and Jimenez 2021). A similar approach was proposed two decades earlier before the emergence of either SARS or SARS-CoV-2 (Rudnick and Milton 2003). ASHRAE does not recommend a specific CO_2 concentration as a metric of infection risk or ventilation adequacy, but other organizations have issued guidance on indoor CO_2 concentrations in response to the pandemic (Centers for Disease Control and Prevention [CDC 2021] in the United States; Federation of European Heating, Ventilation and Air Conditioning Associations [REHVA 2021] in Europe; and Environmental Modelling Group and Scientific Pandemic Insights Group on Behaviours [EMG/SPI-B 2021] in the United Kingdom) or mandated (Belgian Federal Government [BFG 2021]) CO_2 concentration limits.

Many published limits are based on CO_2 as an indicator of the outdoor ventilation rate per person, which implicitly involves the use of CO_2 as a tracer gas along with a target ventilation rate. The ventilation rates on which these CO_2 concentrations are based may be derived from ventilation

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

standards that are not based on the control of airborne disease transmission except in healthcare settings, or from a ventilation rate specifically intended to control transmission. Note that the ventilation requirements in ASHRAE Standard 62.1 (2022) are a function of space use and occupancy and therefore the corresponding indoor CO_2 concentration varies by space type. For example, the steady-state CO_2 concentrations corresponding to the ventilation requirements in Standard 62.1 range from about 1000 ppm_v in office spaces and classrooms with younger students to between 1500 and 2000 ppm_v in restaurants, lecture classrooms, and retail spaces to above 2500 ppm_v in conference rooms and auditoriums. Recommendations or requirements for ventilation rates and CO_2 concentrations to limit infectious disease transmission have been suggested but are highly uncertain given the many factors that impact infection risk, including differences between pathogens. It is important to bear in mind that ventilation is only one control strategy that should be implemented as part of a layered approach to risk management.

Higher CO_2 concentrations do correspond to lower outdoor air ventilation rates and potentially an increased risk of airborne transmission. While CO_2 concentrations can be a useful qualitative indicator, they do not capture the impacts of the reduced occupancy that is common in many buildings or the impacts of particle filtration and air cleaning on infection risk, which may be equal or greater to the effect of dilution with outdoor air. Other factors impact exposure and transmission risk, such as the amount of virus in the air (which does not necessarily scale with CO_2), respiratory activity, and type of pathogen. Note also that if CO_2-based DCV is being used, lower occupancy will reduce the outdoor air ventilation rate and potentially increase the risk of transmission, which is why several organizations have recommended disabling DCV systems or lowering their set points. These two strategies will have different impacts on outdoor air ventilation rates, with the former maintaining design minimum outdoor air intake and the latter potentially increasing outdoor air ventilation.

Rather than using indoor CO_2 concentration as an indicator of desired ventilation rates, several analyses of airborne infection risk have used CO_2 as an indicator of the "rebreathed fraction" of indoor air (the fraction of inhaled air that was exhaled by someone else in the space). If the incidence of an airborne disease in the population and the infectious dose of the pathogen are known, these methods can be used to estimate the percentage of new infections for a particular scenario (Rudnick and Milton 2003; Peng and Jimenez 2021). These methods rely on multiple assumptions about the distribution of indoor CO_2 and infectious aerosol, the relative significance of different infection modes, and dose response relationships that are subject to large uncertainties. Consequently, they may not be highly accurate predictors of absolute risk.

An emerging issue is the potential impact of CO_2 concentration on the survival of viruses in respiratory aerosols due to its effect on pH. In a limited number of experiments, elevated CO_2 concentrations have been reported to increase the natural inactivation rate of SARS-CoV-2. These results must be viewed as preliminary and not conclusive until a number of potentially confounding factors are investigated.

REFERENCES

Allen, J.G., P. MacNaughton, U. Satish, S. Santanam, J. Vallarino, and J.D. Spengler. 2016. Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: A controlled exposure study of green and conventional office environments. *Environ. Health Perspect.*, 124, 805–12.

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

Allen, J.G., P. MacNaughton, J.G. Cedeno-Laurent, X. Cao, S. Flanigan, J. Vallarino, et al. 2018. Airplane pilot flight performance on 21 maneuvers in a flight simulator under varying carbon dioxide concentrations. *J Expos Sci Environ Epid* 08:08.

Apte, M.G., W.J. Fisk, and J.M. Daisey. 2000. Associations between indoor CO_2 concentrations and sick building syndrome symptoms in US office buildings: An analysis of the 1994–1996 BASE study data. *Indoor Air* 10 (4):246–57.

ASHRAE. 2022a. ANSI/ASHRAE/IES Standard 90.1-2022, *Energy standard for buildings except low-rise residential buildings*. Peachtree Corners, GA: ASHRAE.

ASHRAE. 2022b. ANSI/ASHRAE Standard 62.1-2022, *Ventilation for acceptable indoor air quality*. Peachtree Corners, GA: ASHRAE.

ASTM. 2024. ASTM E741-11(2017), *Standard test method for determining air change in a single zone by means of a tracer gas dilution*. West Conshohocken, PA: ASTM International.

ASTM. 2024. ASTM D6245-24, *Standard guide on the relationship of indoor carbon dioxide concentrations to indoor air quality and ventilation*. West Conshohocken, PA: ASTM International.

Balling, R.C. Jr, R.S. Cerveny, and C.D. Idso. 2001. Does the urban CO_2 dome of Phoenix, Arizona contribute to its heat island? *Geophysical Research Letters* 28(24):4599– 4601.

BFG. 2021. Belgian pandemic emergency decree. Belgian Federal Government – Ministry of Internal Affairs. www.ejustice.just.fgov.be/eli/besluit/2021/10/28/2021042995/justel.

CDC. 2021. Ventilation in buildings. Atlanta: Centers for Disease Control and Prevention. www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html.

CEN. 2019. CEN 16798-1:19, *Energy performance of buildings – Ventilation for buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*. Brussels: European Committee for Standardization.

Cleveland, W.S., A.E. Freeny, and T.E. Graedel. 1983. The seasonal component of atmospheric CO_2: Information from new approaches to the decomposition of seasonal time series. *Journal of Geophysical Research: Oceans* 88(C15):10934–46.

Du, B., M.C. Tandoc, M.L. Mack, and J.A. Siegel. 2020. Indoor CO_2 concentrations and cognitive function: A critical review. *Indoor Air* 30(6):1067–82.

Emmerich, S.J., and A.K. Persily. 1997. Literature review on CO_2-based demand-controlled ventilation. *ASHRAE Transactions* 103(2):229–43.

EPA. 2021. Climate change indicators: Atmospheric concentrations of greenhouse gases. www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases. Site visited September 12, 2024.

Fisk, W., P. Wargocki, and X. Zhang. 2019. Do indoor CO_2 levels directly affect perceived air quality, health, or work performance? *ASHRAE Journal* 61(9):70–77.

Fisk, W.J. 2017. The ventilation problem in schools: Literature review. Indoor Air 27: 1039–51.

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

Gaihre, S., S. Semple, J. Miller, S. Fielding, and S. Turner. 2014. Classroom carbon dioxide concentration, school attendance, and educational attainment. *Journal of Schoo*l *Health* 84(9):569–74.

Hu, S.-C., A. Shiue, S.-M. Chang, Y.-T. Chang, C.-H. Tseng, C.-C. Mao, A. Hsieh, and A. Chan. 2017. Removal of carbon dioxide in the indoor environment with sorption-type air filters. *International Journal of Low-Carbon Technologies* 12(3):330–34. https://doi.org/10.1093/ijlct/ctw014.

ISO. 2017. ISO 12569:2017, *Thermal performance of buildings and materials – Determination of specific airflow rate in buildings – Tracer gas dilution method*. Geneva: International Organization for Standardization.

Jacobson, M. 2010. Enhancement of Local Air Pollution by Urban CO_2 Domes. *Env. Sci. Technol*. 44: 2497-2502.

Jacobson, T.A., J.S. Kler, M.T. Hernke, R.K. Braun, K.C. Meyer, and W.E. Funk. 2019. Direct human health risks of increased atmospheric carbon dioxide. *Nature Sustainability* 2:691–701.

James, J.T., and S.M. Zalesak. 2013. Surprising effects of CO_2 exposure on decision making.

43rd International Conference on Environmental Systems, Vail, Colorado.

Kabirikopaei, A., and J. Lau. 2020. Uncertainty analysis of various CO_2-based tracer-gas methods for estimating seasonal ventilation rates in classrooms with different mechanical systems. *Building and Environment*, 179.

Kajtar, L., and L. Herczeg. 2012. Influence of carbon-dioxide concentration on human well- being and intensity of mental work. *Idojaras* 116:145–69.

Lee, J., T.W. Kim, C. Lee, and C. Koo. 2022. Integrated approach to evaluating the effect of CO_2 concentration on human cognitive performance and neural responses in office environment. *J. Management in Engineering* 38(1).

Lietzke, B., and R. Vogt. 2013. Variability of CO_2 concentrations and fluxes in and above an urban street canyon. *Atmospheric Environment* 74:60–72.

Lin, X., and J. Lau. 2015. Demand controlled ventilation for multiple zone HVAC systems: Part 2 – CO_2-based dynamic reset with zone primary airflow minimum setpoint reset (1547-RP). *Science and Technology for the Built Environment* 21(8):1100–1108.

Liu, M., J. Wu, X. Zhu, H. He, W. Jia, and W. Xiang. 2015. Evolution and variation of atmospheric carbon dioxide concentration over terrestrial ecosystems as derived from eddy covariance measurements. *Atmospheric Environment* 114, 75–82.

Lowther, S.D., S. Dimitroulopoulou, K. Foxall, C. Shrubsole, E. Cheek, B. Gadeberg, and O. Sepai. 2021. Low level carbon dioxide indoors—A pollution indicator or a pollutant? A health-based perspective. *Environments*, 8.

Lu FT, Gupta D, Fiedler N, Satish U, Black KG, Legard A, De Resende A, Guo C, Gow AJ, Kipen HM. Mechanisms Underlying Acute Cognitive Impairment following Carbon Dioxide Inhalation in a Randomized Crossover Trial. Environ Health Perspect. 2024 Oct;132(10):107702. doi: 10.1289/EHP14806. Epub 2024 Oct 28. PMID: 39466336; PMCID: PMC11515854.

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

Lu, X., P. Zhihong, F. Yangyang, and Z. O'Neill. 2022. The nexus of the indoor CO_2 concentration and ventilation demands underlying CO_2-based demand-controlled ventilation in commercial buildings: A critical review. *Building and Environment*, 218.

Mendell, M.J., Chen, W., Ranasinghe, D.R. et al. Carbon dioxide guidelines for indoor air quality: a review. *J Expo Sci Environ Epidemiol* 34, 555–569 (2024). https://doi.org/10.1038/s41370-024-00694-7

NIOSH. 1976. *Criteria for a recommended standard: Occupational exposure to carbon dioxide*. DHHS (NIOSH) Publication Number 76-194. National Institute for Occupational Safety and Health. www.cdc.gov/niosh/docs/76-194.

NOAA. 2024. Trends in atmospheric carbon dioxide. https://gml.noaa.gov/ccgg/trends/. Site visited September 11, 2024.

OSHA. 2017. Limits for air contaminants. Washington, DC: Occupational Safety & Health Administration, U.S. Department of Labor. www.osha.gov/laws-regs/regulations/standard number/1910/1910.1000TABLEZ1.

Peng, Z., and J.L. Jimenez. 2021. Exhaled CO_2 as a COVID-19 infection risk proxy for different indoor environments and activities. *Environmental Science & Technology Letters*, 8, 392–97.

Persily, A. 2015. Challenges in developing ventilation and indoor air quality standards: The story of ASHRAE Standard 62. *Building and Environment* 91, 61–69.

Persily, A. 2022. Development and application of an indoor carbon dioxide metric. *Indoor Air. 32*, e13059

REHVA. 2021. REHVA COVID-19 Guidance, version 4.1. Brussels, Belgium: Federation of European Heating, Ventilation and Air Conditioning Associations. www.rehva.eu/file admin/user_upload/REHVA_COVID-19_guidance_document_V4.1_15042021.pdf.

Rudnick, S.N., and D.K. Milton. 2003. Risk of indoor airborne infection transmission estimated from carbon dioxide concentration. *Indoor Air* 13(3):237–45.

EMG/SPI-B. 2021. Application of CO_2 monitoring as an approach to managing ventilation to mitigate SARS-CoV-2 transmission. www.gov.uk/government/publications/emg-and- spi-b-application-of-co2-monitoring-as-an-approach-to-managing-ventilation-to-mitigate

-sars-cov-2-transmission-27-may-2021.

Satish, U., M.J. Mendell, K. Shekhar, T. Hotchi, D. Sullivan, S. Streufert, et al. 2012. Is CO_2 an indoor pollutant? Direct effects of low-to-moderate CO_2 concentrations on human decision-making performance. *Envir Health Persp* 120:1671–77.

Scully, R.R., M. Basner, J. Nasrini, C.W. Lam, E. Hermosillo, R.C. Gur, T. Moore, D.J. Alexan- der, U. Satish, and V.E. Ryder. 2019. Effects of acute exposures to carbon dioxide on decision making and cognition in astronaut-like subjects. *NPJ Microgravity*, 5, 17.

Shendell, D.G., R. Prill, W.J. Fisk, M.G. Apte, D. Blake, and D. Faulkner. 2004. Associations between classroom CO_2 concentrations and student attendance in Washington and Idaho. *Indoor Air* 14(5):333–41.

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

Thom, S.R., V.M. Bhopale, J.P. Hu, and M. Yang. 2017a. Inflammatory responses to acute elevations of carbon dioxide in mice. *J Appl Physiol* 123: 297–307.

Thom, S.R., V.M. Bhopale, J.P. Hu, and M. Yang. 2017b. Increased carbon dioxide levels stimulate neutrophils to produce microparticles and activate the nucleotide-binding domain- like receptor 3 inflammasome. *Free Radical Biology and Medicine* 106:406–16.

Wargocki, P. 2021. What we know and should know about ventilation. *REHVA Journal* 58(2):5–13.

Wei, W., O. Ramalho, and C. Mandin. 2015. Indoor air quality requirements in green building certifications. *Building and Environment* 92:10–19.

Wei, W., P. Wargocki, J. Zirngibl, J. Bendžalová, and C. Mandin. 2020. Review of parameters used to assess the quality of the indoor environment in Green Building certification schemes for offices and hotels. *Energy and Buildings*, 209:109683.

Zhang, X., P. Wargocki, Z. Lian, and C. Thyegod. 2016a. effects of exposure to carbon dioxide and bioeffluents on perceived air quality, self-assessed acute health symptoms and cognitive performance. *Indoor Air* 27, 47–64.

Zhang, X., P. Wargocki, and Z. Lian. 2016b. Human responses to carbon dioxide, a follow-up study at recommended exposure limits in non-industrial environments. *Building and Environment* 100, 162–71.

ADDITIONAL ASHRAE RESOURCES

All resources should be cited in the text, properly elaborated so that they clearly support any relevant statements. ASHRAE's preferred method of citation, widely used in scientific texts, is the author-date method. Follow ASHRAE Authors' Manual.

OTHER RESOURCES

All resources should be cited in the text, properly elaborated so that they clearly support any relevant statements. ASHRAE's preferred method of citation, widely used in scientific texts, is the author-date method. Follow ASHRAE Authors' Manual.

DOCUMENT REVISION COMMITTEE ROSTER

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

The ASHRAE Position Document on Indoor Carbon Dioxide was developed by the Society's Position Document Revision Committee formed on February 13, 2020, with Andrew Persily as its chair.

Andrew Persily, PhD

National Institute of Standards and Technology
Gaithersburg, Maryland, USA

Corinne Mandin, PhD

Institute for Radiation Protection and Nuclear Safety (IRSN), France

William P. Bahnfleth, PhD, PE

The Pennsylvania State University

University Park, Pennsylvania, USA

Chandra Sekhar, PhD

National University of Singapore

Singapore

Howard Kipen, MD, MPH

Rutgers University – School of Public Health
Piscataway New Jersey, USA

Pawel Wargocki, PhD Technical University of Denmark Copenhagen, Denmark

Josephine Lau, PhD

University of Nebraska Lincoln,

Nebraska, USA

Lan Chi Nguyen Weekes, PEng, ing.

La Cité College Ottawa,

Ontario, Canada

Cognizant Committees

The chair of ASHRAE's Environmental Health Committee also served as ex-officio member.

Marwa Zaatari, PhD

D Zine Partners

Austin Texas, USA

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

DOCUMENT HISTORY

Publication and Revision History

ASHRAE's Technology Council and the cognizant committee recommend revision, reaffirmation, or withdrawal every 30 months.

The following summarizes the revision, reaffirmation or withdrawal dates:

2/2/2022—BOD approves Position Document titled *ASHRAE Position Document on Indoor Carbon Dioxide*

© 2022 ASHRAE ● 180 Technology Parkway ● Peachtree Corners, Georgia 30092 USA ● www.ashrae.org. For personal use only.
Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.