MINUTES (DRAFT)

Environmental Health Committee (EHC)
January 21, 2021
Virtual Winter Meeting

These minutes have not been approved and are not the official, approved record until approved by this committee.

MEMBERS PRESENT:
Wei Sun, *Chair*
Luke Leung, *Vice-Chair*
Peter Alspach
Bill Bahnfleth
Charlene Bayer
Brendon Burley
Nicholas Clements
John Cohen
Karel Kabele
Kishor Khankari
Claressa Lucas
Rick Hermans, *BOD Ex-O*
Andy Persily
Bill McQuade, *Coord. Officer*
Stephanie Taylor
Wayne Thomann

MEMBERS NOT PRESENT:
Peter Alspach

ASHRAE STAFF:
Steve Hammerling, *MOTS*
Stephanie Reiniche, *Director of Technology*

GUESTS:
Costas Balaras
Wane Baker
Lauren Berton
Wade Conlan
Darryl DeAngelis
Steve Emmerich
Jeremy Fauber
Henry Greist
Lew Harriman
Elliott Horner
Dennis Knight
Daniel Malashock
Frederick Marks
Stephany Mason
Meghan McNulty
LanChi Nguyen-Weekes
Larry Schoen
Max Sherman
Larry Smith
Pawel Wargocki
Don Weekes
Steve Welty

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MOTIONS

No.	Motion	STATUS
1	the minutes from the December 2nd meeting be approved.	PASSED
2	EHC recommends that DRSC recommends to Tech Council to appoint Walter Vernon as chair of the Infectious Aerosols PD committee.	PASSED
3	EHC recommends that DRSC recommends to Tech Council to set aside 4.2.b in Attachment B, ASHRAE Position Documents, to the Tech Council MOP in considering the size of the Infectious Aerosols position document Committee.	PASSED
4	EHC recommends that DRSC recommend to Tech Council that they appoint the following members to the Infectious Aerosols position document committee: ***[See the name list in Subcommittee report]***	PASSED
5	EHC recommends that DRSC recommends to Tech Council to appoint Pawel Wargocki as chair of the Filtration and Air Cleaning PD committee.	PASSED
6	EHC recommends that DRSC recommend that Tech Council reaffirm the *Filtration and Air Cleaning* Position Document (PD).	PASSED

LIST OF ATTACHMENTS

No.	Attachment
A	MBOs 2020-2021
B	BOD Ex-O presentation
C	Walter Vernon bio
D	Infectious Aerosols PD committee bios
E	Pawel Wargocki bio
F	Filtration and Air Cleaning PD
G	Elevation and Acceptable IAQ
H	VRP Density Correction

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AEDG	Advanced Energy Design Guide
AI	Action Item
AiCARR	Italian Association of Air Conditioning, Ventilation and Refrigeration
AIHA	American Industrial Hygiene Association
AIVC	Air Infiltration and Ventilation Centre
ASA	Acoustical Society of America
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
A&WMA	Air & Waste Management Association
BOD	Board of Directors
CNV	Chair Not Voting
CV's	curriculum vitae
DRSC	Document Review Subcommittee
EHC	Environmental Health Committee
EIB	Emerging Issue Brief
ETF	Epidemic Task Force
ExCom	Executive Committee
ExO	Ex-Officio
GAC	Government Affairs Committee
GPC	Guideline Project Committee
H&A	Honors & Awards
HVAC&R	Heating, Ventilating, Air Conditioning & Refrigeration
HWBE	Health & Wellness in the Built Environment
IAQ	Indoor Air Quality

IAQA	Indoor Air Quality Association
IEQ	Indoor Environmental Quality
IEQ-GA	Indoor Environmental Quality Global Alliance
IgCC	International Green Construction Code
IICRC	Institute of Inspection Cleaning and Restoration Certification
ISHRAE	Indian Society of Heating, Refrigerating and Air Conditioning Engineers
ISIAQ	International Society of Indoor Air Quality and Climate
MBO	Management by Objectives
MOP	Manual of Procedures
MOTS	Manager of Technical Services
MTG	Multi-disciplinary Task Group
PD	Position Document
PMS	Project Monitoring Subcommittee
REHVA	Representatives of European Heating and Ventilation Associations
ROB	Rules of the Board
RP	Research Project
RTAR	Research Topic Acceptance Request
SIE	Society for Indoor Environment
SSPC	Standing Standard Project Committee
TAC	Technical Activities Committee
TC	Technical Committee
WHO	World Health Organization
WS	Work Statement

ACTION ITEMS FROM 2021 WINTER MEETING

No.	Responsibility	Action Item	Status
1	EHC	Khankari asked for thoughts from members to “identify major trends impacting environmental health related with HVACR for a report to Tech Council.	Ongoing
2	EHC	Send Bayer program ideas for Annual meeting by Feb 22 deadline.	Complete
3	Persily	Send email request for IEQ column articles	Ongoing
4	EHC	Send ideas for EHC seminar presentation ideas to Bayer.	TBD in March
5	Persily, Alspach, EHC	Develop a work plan to develop a high performance IEQ publication	TBD
6	Burley, EHC	Burley agreed to develop a discussion group to study 62.1 ventilation rates at high elevation	Ongoing
7	EHC	Fill out Leung’s survey of groups (inside and outside of ASHRAE) with contacts to pursue interaction/discussion on topics that impact environmental health	Ongoing

ACTION ITEMS FROM DEC 2, 2020 MEETING

No.	Responsibility	Action Item	Status
1	EHC	Respond to letter ballot on Environmental Health Award.	Closed
2	EHC	Send topics/speakers for a spring seminar to Bayer.	Ongoing
3	Staff	Communicate result of PD chair motions to DRSC and Tech Council for their consideration	Complete
4	EHC	Leung asked members who in the industry would be best suited to identify future health and buildings trends	Ongoing
5	EHC	Send comments on Research Advisory Panel (RAP) draft strategic plan initiative on IEQ to Wargocki	Ongoing
6	Persily/ Alspach	Give “High performance vs. acceptable or minimum standards” presentation at next EHC meeting	Complete
7	Burley	Give presentation on ‘air density corrections in 62.1’ at next EHC meeting.	Complete
8	Outreach	Add study on effectiveness of temporary health care units to list of possible future work.	Complete

1. CALL TO ORDER & INTRODUCTIONS

Chair Sun called the meeting to order at approximately 2:30 PM EST. Members and guests introduced themselves. Quorum was confirmed.

2. ASHRAE CODE OF ETHICS COMMITMENT

'In this and all other ASHRAE meetings, we will act with honesty, fairness, courtesy, competence, integrity and respect for others, and we shall avoid all real or perceived conflicts of interests.' (See full Code of Ethics: www.ashrae.org/about-ashrae/ashrae-code-of-ethics.)

3. REVIEW OF AGENDA

It was requested that an item (5.A.1) be inserted on the letter ballot on interim GPC44 guidance.

4. MINUTES

It was moved (WT) and seconded (KK) that,

(1) the minutes from the December 2nd meeting be approved.

BACKGROUND: Draft minutes were sent to committee in January 18th email.

MOTION 1 PASSED: 10-0-0, CNV

5. CHAIR'S REPORT (Sun)

A. Motions from Past Meetings Requiring Higher Body Approval
   1. Letter ballots
      a) Motion to approve interim guidance from GPC44
         This motion passed EHC with negative votes (8-2-0-4-1). As this was a letter ballot with negative votes, it would be required to be reissued with reasons for negative votes for reconsideration. Sun opted to forward comments to Emmerich for consideration as formal approval from EHC was not necessary to post to the Epidemic Task Force (ETF) website.

      b) Motion to approve Environmental Health Award winner.
         This motion is closed. Will be discussed later on agenda.

   2. Dec 2 meeting
      a) *EHC recommends that Walt Vernon chair the Infectious Aerosols Position Document Committee* - This motion will be considered by DRSC/Tech Council at their Winter Meeting

      b) *EHC recommends that Pawel Wargocki chair the Filtration and Air Cleaning Position Document Committee* - This motion will be considered by DRSC/Tech Council at their Winter Meeting.

B. 2020-2021 Management by Objectives (MBOs)
   A summary of all MBOs will be reported to Tech Council (**Attachment A**). Sun noted there were two new MBOs (with assignments) added to address the ASHRAE Strategic Plan Initiative on Indoor Environmental Quality (IEQ).

C. Other
   EHC hosted a seminar on January 8 titled "EHC Seminar – Epidemic Task Force Update". It included 4 speakers from the ETF and was very well attended. More details will be discussed in ETF report later.

6. VICE-CHAIR'S REPORT (Leung)

A. ROB/MOP/Reference Manual
   No changes to these documents are proposed at this time.

B. Donald Bahnfleth Environmental Health Award
The letter ballot to consider three nominees is now closed. The winner was sent to Honors & Awards (H&A) committee for their formal consideration.

C. Other
Leung would develop 21-22 MBOs before the Annual Meeting. New MBOs addressing the ASHRAE Strategic Plan Initiative would be included.

7. BOARD OF DIRECTORS (BOD) EX-OFFICO (EXO) & COORDINATING OFFICER REPORT

A. BOD EX-Officio - Hermans
Hermans asked for new EHC member nominations to be submitted to www.ashrae.org/committee-nominations by Feb 19th deadline.

Hermans did not give Ex-O presentation for time reasons but asked that presentation be attached to minutes (**Attachment B**).

B. Coordinating Officer
Coordinating Officer McQuade addressed EHC and thanked all for their work. He noted ASHRAE is seeking operating expense reductions for budgets and asked EHC for ideas.

McQuade noted that similarly to EHC's work to address a strategic plan initiative, Technical Committee (TC) 2.10 is working on a workplan to address a resiliency initiative. EHC may wish to refer to the TC 2.10 work plan as a template when available.

8. SUBCOMMITTEE REPORTS

A. Policy Subcommittee (**Khankari**)

1. Identify major environmental health trends impacting environmental health related with HVAC&R

   Khankari asked for thoughts from members, ETF members, etc. This effort is related to MBO #2 to "Draft a short report to Tech Council which identifies major trends impacting environmental health related with HVAC&R." (**AI #1**).

2. Position Document (PD) Oversight

   a) *Infectious Aerosols*

   It was moved (JC) and seconded (CL) that,

   (2) EHC recommends that DRSC recommends to Tech Council to appoint Walter Vernon as chair of the Infectious Aerosols PD committee.

   BACKGROUND: Mr. Vernon's ASHRAE bio is included as **Attachment C**. BOD ExCom approved initiating a revision to this PD at the Annual Meeting.

   MOTION 2 PASSED: 13-0-0 CNV

   It was moved (KK) and seconded (WT) that,

   (3) EHC recommends that DRSC recommends to Tech Council to set aside 4.2.b in Attachment B, ASHRAE Position Documents, the Tech Council MOP in considering the size of the *Infectious Aerosols* position document committee.

BACKGROUND: 4.2.b in Attachment B, ASHRAE Position Documents, of the Tech Council MOP notes the following: *The size of the Position Document Committee should be no less than five (5) and no more than eight (8) members and provide a good cross-section of the technical aspects of the issue and perspectives of parties at interest. The intent is that all members are classified as voting members.*

A PD committee of 12 members is recommended for the Infectious Aerosols PD Committee to assure adequate representation from the various fields and organizations with interest and expertise in the Infectious Aerosols. 4.2.a in Attachment B, ASHRAE Position Documents, of the Tech Council notes the following: *The committee shall be knowledgeable in the discipline of the subject of the Position Document and the public-policy dimensions of the issue.*

MOTION 3 PASSED: 13-0-0 CNV

It was moved (JC) and seconded (CL) that,

(4) EHC recommends that DRSC recommends to Tech Council that they appoint the following members to the *Infectious Aerosols* position document committee:

- Bill Bahnfleth, Pennsylvania State University
- Jamechia Hoyle, National Center for Biomedical Research & Training
- Paul Jensen, retired
- Kishor Khankari, AnSight
- Yuguo Li, Hong Long University
- Linsey Marr, Virginia Tech
- Jovan Pantelic, UC Berkeley
- Nathalie Robbel, WHO
- Chandra Sekhar, National University of Singapore
- Dave Sine, Veterans Administration
- Wayne Thomann, Duke University

BACKGROUND: The proposed members represent various fields, outside experts, and relevant ASHRAE committees. ASHRAE bios for ASHRAE members and CV's for non-members are summarized in **Attachment D**. The World Health Organization (WHO) has expressed a strong interest in participating and co-publishing the position document. It was noted an advisory panel may be developed and reached out to as appropriate. The advisory group would not be members of the PD committee.

MOTION 4 PASSED: 13-0-0 CNV

b) Filtration and Air Cleaning

It was moved (KK) and seconded (WT) that,

(5) EHC recommends that DRSC recommends to Tech Council to appoint Pawel Wargocki as chair of the *Filtration and Air Cleaning* PD committee.

BACKGROUND: Mr. Wargocki's ASHRAE bio is included as **Attachment E**. BOD ExCom approved initiating a revision to this PD at the Annual Meeting. If approved, Wargocki will work with EHC to develop a committee roster.

MOTION 5 PASSED: 13-0-0 CNV

It was moved (KK) and seconded (WT) that,

(6) EHC recommends that DRSC recommend that Tech Council reaffirm the *Filtration and Air Cleaning* Position Document (PD).

BACKGROUND: A revision is underway now, but the current PD (**Attachment F**) expires January 23, 2021. Reaffirming the PD would keep this document available until a revision is ready.

MOTION 6 PASSED: 13-0-0 CNV

c) *Limiting Indoor Mold and Dampness in Buildings*
Lew Harriman was formally appointed as chair by Tech Council. Harriman noted 2012 was the last major rewrite and the PD expires in June. The main task for the PD revision is to edit to bring to appropriate size, reference recent updates to ASHRAE Standards and publications, etc. He is working to develop a PD committee. Four of the seven members he had in mind have confirmed their willingness to participate. Harriman aims to have roster for EHC in February.

d) *Indoor Carbon Dioxide*
Persily reported that development of the *Indoor Carbon Dioxide* PD is underway. A draft for EHC to review is anticipated this spring.

3. Other
No new policy documents (PD, EIB) were proposed at this time.

B. <u>Education Subcommittee (Bayer)</u>

1. EHC Sponsored Programs for Winter Meeting
EHC is a co-sponsor (with TC 9.12) for a seminar titled *Present and Future Challenges in Ventilation Unique to Tall Buildings Arising from Epidemics, Health Issues and Climate Change*. All are encouraged to attend.

2. EHC Program Proposals for Annual Meeting
Applications for Annual Meeting seminars are due February 22. The website (www.ashrae.org/phoenix) is operational and features eight tracks plus a mini-track. Bayer asked all to send her program ideas (**AI #2**).

3. ASHRAE Journal IEQ Applications Column
Persily invited authors to submit articles in near future. He agreed to email EHC in next week with details (**AI #3**).

4. Handbook Chapter
The next revision for the 2025 publication will be due in 2024. The revised chapter in the 2021 volume will be released later this year. Bayer will be seeking volunteers to assist in the update effort soon but has not yet done so.

5. Online short presentations/seminars to EHC and beyond
The ETF seminar will be discussed later on the agenda. This was the first of these EHC planned

and presented seminars. EHC would plan for another seminar later in the spring on a traditional environmental health topic. This would include 4-5 speakers with 15-20-minute presentations with opportunities for questions and answers. EHC members were asked to suggest topics/speakers and work with Bayer (**AI #4**). Khankari suggested recording these seminars going forward. Possible ideas could include building preparedness, climate change, pets and animals in indoor spaces, IEQ in pets and animal facilities, indoor aerosol/particle control and modeling, etc.

Wargocki proposed to solicit 4-5 technical speakers to prepare the second ETF seminar in Spring, to cover additional topics that were not included during the first ETF seminar arranged and moderated by Bahnfleth on January 8, 2021. The second ETF seminar's speech topics/speakers will be selected.

6. Other
Persily led a discussion originally planned for last December meeting on high performance versus acceptable or minimum standards. Persily asked what EHC can do to work towards high performance indoor environmental quality (IEQ). Can EHC spearhead an Advanced Energy Design Guide (AEDG) type effort related to IEQ, Advanced IEQ Guides? Can EHC help develop a practitioner based high performance IEQ design guide? This would have to relate to current ASHRAE publications such as GPC42, the Residential IAQ guide, and others. Persily would discuss with Alspach but is seeking volunteers with an interest to help develop a plan (**AI #5**).

Burley, Fauber and DeAngelis gave presentations on "Elevation and Acceptable IAQ" (**Attachment G)** and "VRP Density Correction" (**Attachment H**). There are proposals to SSPC 62.1 to account for elevation corrections. EHC suggested further study versus a formal change proposal to the standard to see if this there are problems at higher elevations with current ventilation rates. Burley agreed to develop a discussion group with volunteers from EHC and his working group (**AI #6**).

C. Coordination and Outreach Subcommittee (Clements)

1. Interaction with ASHRAE committees
Clements noted the subcommittee met December 9 and has a Basecamp site established. They have identified a list of TCs to liaise with. Technical Activities Committee (TAC) can help to communicate with the identified TCs before the Annual Meeting to establish a relationship. communications will include research ideas to share, a short list of references, point of contact, etc. The next subcommittee meeting will be in late February.

2. Interaction with outside organization that impact environmental health
Leung noted this would be developed as part of MBO #10. Leung distributed a link to a google document - https://docs.google.com/spreadsheets/d/1zjhyDdrZrb1GJr2LWxBQr4DvYVrdJvdWTGtoK58IZqQ/edit#gid=744524000. Leung asked members to fill out the survey questions and add to list of groups (inside and outside of ASHRAE) with contacts (**AI #7**).

3. IAQ 2020
Bahnfleth noted the IAQ 2020 Conference, *IEQ Performance Approaches, Transitioning from IAQ to IEQ*, is moved to September 13-15, 2021. The conference will take place in Athens, Greece as a face to face meeting but may be a hybrid format given the possibility of travel restrictions. Chair's Bill Bahnfleth and Max Sherman are chairing the event which will be co-organized by ASHRAE, AIVC and the IEQ-GA. The steering committee has been meeting periodically. Details on the conference can be found at www.ashrae.org/iaq2020. There have been a number of great presentation submissions. A special edition of the ASHRAE Science and Technology for the Built Environment (STBE) Journal is planned to highlight these submissions. The steering committee is now actively seeking co-sponsorship.

4. Indoor Environmental Quality – Global Alliance (IEQ-GA)
   ASHRAE continues to participate in the IEQ-GA. Don Weekes is the current President with Bill Bahnfleth as the ASHRAE representative. Weekes reported the IEQ-GA is now finalized as a legal entity and operates with nine full member organizations (ACGIH, AICARR, AIHA, AIVC, ASA, ASHRAE, IICRC, ISHRAE, REHVA) and three affiliate members (A&WMA, IAQA, SIE). IEQ-GA (www.ieq-ga.net) has collected and posted COVID-19 related resources, answers to common questions, and other resources from the various member organizations. They are exploring a series of podcasts with ISIAQ, and IEQ book, webinars, and other efforts.

   Weekes noted that IEQ-GA aims to continue to work closely with ASHRAE in the future. The IEQ-GA is always looking for more members. EHC members are asked to suggest organizations that should participate in the IEQ-GA.

5. ASHRAE Epidemic Task Force
   ETF chair Bill Bahnfleth noted EHC's seminar on the ETF was a great success. The EHC hosted seminar was held January 8 and titled "EHC Seminar – Epidemic Task Force Update". The speakers and topics were:
   - Bill Bahnfleth – ETF Guidance
   - Pawel Wargocki – Science Applications Team
   - Rick Hermans – Research Agenda
   - Terry Townsend – Advocacy, Government Affairs

   125+ EHC members, ETF team members, the ASHRAE BOD and various interested parties attended the seminar. A second ETF technical seminar will be scheduled for late March or early April. Another seminar on traditional EHC topics will be provided in mid or late April 2021.

   Bahnfleth added that the various ETF teams continue to develop and update guidance. There are now 400+ pages at www.ashrae.org/covid19.

6. List of research topics with brief descriptions to document emerging ideas to TCs as inspiration for potential research
   Research ideas will be developed as part of the MBOs #9 and 13

7. Current EHC sponsored or co-sponsored research
   a) Active Research Projects
      - RP-1579 - *Testing and Evaluation of Ozone Filters for Improving IAQ*
        Hoy Bohanon is EHC's representative on the Project Monitoring Subcommittee (PMS) for 1579 and submitted the following winter report:
        1. The PMS met this week and will meet again after receiving the report, expected next month.
        2. Almost all of the tests are complete and the research team is in the process of writing the report.
        3. Initial results show that there are differences in various filter types and that efficiency is affected by environmental conditions

9. LIAISON ACTIVITIES

A. GAC (McNulty)
   McNulty introduced herself as a new liaison to EHC from the Government Affairs Committee (GAC). McNulty thanked EHC for technical work which is of great interest to GAC and is the basis of their

advocacy work. The EIBs one-pagers have been great tool as have the position documents developed through EHC.
GAC wishes to collaborate with EHC on development the documents EHC is working on. There is currently a demand for ASHRAE comments on vaping and cannabis use in a PD or EIB. Nick Clements will be EHC's liaison to the GAC.

B. Standard 62.1 (Thomann)
Thomann noted there are two SSPC 62.1 sponsored seminars that will be part of ASHRAE Winter Meeting. Bohanon added that the SSPC did not pass an addendum on including low humidity limits in 62.1 and invited Stephanie Taylor to participate in their next meeting on January 29th.

Wei Sun noted ASHRAE is seeking a reviewer a Standard 62.1-related ASHRAE Journal article. Taylor volunteered for this effort.

C. Standard 62.2
Sherman reported that the ASHRAE BOD approved addendum 62.2a. EHC has voted to recommend publication. Appeals have been filed so the addendum has not been published. The SSPC is seeking members with IAQ or environmental health backgrounds to participate so EHC members are encouraged to join. Sherman and Emmerich will be listed as EHC liaison going forward.

D. Standard 189.1
Persily noted Standard 189.1 was republished in 2020. This version will serve as the technical content for the 2021 International Green Construction Code (IGCC). Persily encouraged all to participate and engage in public reviews of ASHRAE Standards and Guidelines.

E. Standard 170
Burley reported that the SSPC 170 Winter meetings will be held next week. There are no recent updates as they've not met since EHC's last meeting in early December.

F. Guideline 44P
Emmerich noted the discussion of Guideline 44 interim guidance was held earlier.

G. Guideline 42P
Burley stated a new revision of this guideline has been presented. A motion to approve for public review (or an advisory public review) is anticipated when the committee meets on February 2nd.

H. MTG on Health and Wellness
Elliott Horner noted a final report from the MTG is expected to be available before EHC's next meeting.

I. MTG.ACR Air Change Rate
Khankari noted the MTG is sponsoring Seminar 25 at the ASHRAE Winter Meeting and invited all to attend. The MTG continues work to complete ASHRAE research project 1833.

J. MTG.VIC Ventilation for Infection Control
Hermans noted that the MTG met last week. They are currently reviewing an outline for research on infection control protocols. A project to determine the smallest particles that can carry infectious particles is being considered as well.

K. TC 2.1
Yang noted the TC is meeting tomorrow. A new RTAR and two WS's are in the works.

L. Other

No liaisons from Standards 188, 55 and Guideline 10 committee were in attendance.

10. NEW BUSINESS

A. NEXT MEETING

1. EHC will plan on a Spring meeting in late March or early April. Details to be determined.

2. A spring seminar from the ETF will be planned for late March or early April. A 2nd EHC technical seminar would be planned for mid or late April as well.

3. A face to face meeting for the Annual Meeting in Phoenix, AZ (June 29, 2021) is currently being planned for. This could change to another virtual meeting.

11. ADJOURNMENT

Sun adjourned meeting at just after 5 PM EST. All attendees were thanked for their participation.

ATTACHMENT A

MBO Submission to Planning Updated 1/21/2021

Council: Technology Council
Committee: Environmental Health Committee (EHC)
Chair: Wei Sun
Vice-chair: Luke Leung

MBO #	Description	Metric	Initiative #	Goal #	Completion % / Date	Financial Assist Req'd?	MBO Comments	Strategic Plan Talley											
								Initiative #				Goal 1		Goal 2			Goal 3		
		(how do we determine success?)						1	2	3	4	a	b	a	b	c	a	b	c
Policy Subcommittee (Khankari)																			
1	Review published EIB and determine if they need to be retired, reaffirmed, or have a PD created.	Number EIBs retired, reaffirmed, or proposed for PD	1, 2, 3	1a, 3b	On-going	No		x	x	x		x						x	
2	Draft a short report to Tech Council which identifies major trends impacting environmental health related with HVACR.	Report sent to Tech Council	1, 2	1b		No	Itemize each topic with short description in around 50-100 words, the report is of 2 pages maximum. First report expected Winter 2021	x	x				x						
Education Subcommittee (Bayer)																			
3	EHC is to submit at least two society technical programs (paper session/seminar/forum) and to serve as a sponsor or co-sponsor for society annual meeting.	Number Technical programs submitted and/or sponsored	1, 2	1b, 2a		No	Three sponsored/cosponsored Winter Meeting programs	x	x				x	x					
4	Publish at least 7 articles for IEQ Column per year.	Number columns published	1, 2	1b, 2a	On-going	No	Monthly articles on track for near future	x	x				x	x					
5	Develop and propose short online seminars on pandemic related issues (not for regular society annual/winter programs).	Number seminars conducted	1, 2	1b, 2a	On-going	No	Four programs in development for near future	x	x				x	x					
6	Recruit/assign contributors to start revising the Chapter 10.	Number contributors assigned Revision initiated	1, 2, 3, 4	1a, 1b		No	Assigned to Eduation subcommittee but not started as of yet	x	x	x	x	x	x						
Coordination and Outreach Subcommittee (Clements)																			
7	Document the interaction plan with IEQ-GA for future IAQ meetings.	Plan documented	1, 2, 4	2b		No	Relevant to RoB 2.406.003.1	x	x		x				x				
8	Document an interaction plan with Epidemic Task Force (ETF).	Plan documented	1, 2, 4	1b, 2b	On-going	No	Relevant to RoB 2.406.003.1	x	x		x		x		x				
9	Develop a short list of research topics with brief descriptions during each society meeting to document and disseminate emerging research ideas to TCs through TAC as inspiration for potential researches.	List of topics developed Research ideas disseminated	1, 2, 4	1b		No	Each EHC-related topic/descriptions is around 50-100 words (1-2 pages in total). The goal is idea sharing, not to develop RTARs by EHC.	x	x		x		x						
10	Develop a list of EHC-related experts to form an informal discussion group which will regularly in touch to share the latest technical information and trend on what is on the horizon. This could result in policy suggestions, papers, conference programs, research ideas, etc., but is a function of Outreach subcommittee.	List of experts created Policy suggestions developed	1, 2, 4	1b		No	Staff would compile the list of these committees, groups, etc. with contact information to facilitate this outreach.	x	x		x		x						
Administration (Sun/Leung/Hammerling)																			
11	Review the EHC Scope and Manual of Procedures, recommend to maintain or to revise, present recommendation for new language at annual meeting.	Review of MOP completed Reommendations presented	3, 4	3b		No	Relevant to RoB 2.406.001. Changes made to restructure EHC MOP at last meeting			x	x							x	
12	Develop new EIB for concerned items to be published in short order and on ASHRAE website.	EIB published	1, 2	1b, 2a	On-going	No	No new EIBs at this time.	x	x				x	x					
Strategic Plan																			
13	Identify IEQ knowledge gaps and list them in future research priorities	Develop document summarizing gaps and priorities	2		On-going	No	added to address IEQ strategic plan initiative. Meeting Jan 29		x										
14	Develop a roadmap for remaining actions for 2021-2024	Develop roadmap document. Include in next year's MBOs	2		On-going	No	added to address IEQ strategic plan initiative		x										
								11	13	3	6	2	9	4	2	0	0	2	0

ASHRAE Leadership Presentation

Rick Hermans
1/21/2021
EHC Virtual Winter Meeting 2021

1

ASHRAE Policies

Code of Ethics

"We will act with honesty, fairness, courtesy, competence, inclusiveness and respect for others, which exemplify our core values of excellence, commitment, integrity, collaboration, volunteerism and diversity, and we shall avoid all real or perceived conflicts of interest."

Sexual Harassment

ASHRAE is committed to educating members to eliminate all instances of sexual harassment. The Society will deploy an online training program for volunteers to help educate and protect all members, and to sustain the professional environment members deserve and expect. This training will be required prior to serving on certain standing committees and/or in leadership positions.
ashrae.org/about/governance/ashrae-discrimination-and-harassment-policy

Commercialism

ASHRAE's Commercialism Policy allows for Society activities that fulfill the mission of technological advancement with adherence to business plans that generate income to offset operational expenses such as AHR Exposition, ASHRAE periodicals, website, and Society conference events such as the Welcome Party, luncheons, registration kits, and receptions.
ashrae.org/commercialism

View ASHRAE Governing Documents at ashrae.org/about/governance

2

Memoranda of Understanding (MOUs)

National Association of State Energy Officials (NASEO)
November 2020

Chartered Institution of Building Services Engineers (CIBSE)
December 2020

New York State Energy Research & Development Authority (NYSERDA)
July 2020
Umbrella Contract followed this MOU, bringing revenues to ASHRAE.

American Society of Health Care Engineering (ASHE)
July 2020

Air Movement and Control Association (AMCA)
September 2020

Deutscher Kalte und Klimatechnischer Verein (DKV)
July 2020

Kuwait Foundation for the Advancement of Sciences (KFAS)
November 2020

U.S. Department of Homeland Security Science and Technology Directorate
February 2021

Learn more at ashrae.org/mous

3

Financial Impact of COVID-19

- The pandemic economy and loss of the AHR Expo income has strained ASHRAE's budget significantly.
- Membership levels have been impacted but are down less than predicted at the start of SY 2019-20.
- **ASHRAE secured a Payroll Protection Program loan** to help offset some of the losses from operational income. We have applied for loan forgiveness and hope to hear a resolution in the next few months.
- Staff expenses have been reduced, including the downsizing staff from 120 to 110 FTE.
- Volunteer and staff travel expenses have been reduced significantly, reflecting pandemic travel restrictions.

Member Assistance

Due to the financial impact of the COVID-19 pandemic members have experienced, ASHRAE is **not increasing member dues** for the 2020-2021 Society Year.

MCO 3.15 Hardship Cases and Natural Disaster Relief Action. 3.15.1 Hardship Cases

Members Council is responsible for determining what constitutes a hardship case and providing guidance to staff for determination of special consideration with respect to dues and other member benefits. Issues not covered by this guidance shall be ruled on by the chair of Members Council in consultation with staff. For more information, contact **membership@ashrae.org.**

4

Proactive Diversity Task Group

Created June 2020 to recommend detailed programs and initiatives that will seek to eliminate all forms of discrimination and social injustice, and proactively drive diversity, through all levels within ASHRAE.

All Member Survey sent Dec. 2020 received 821 responses. Task Group members are working through survey responses and **welcome your continued feedback** (which can be provided anonymously) here:
ashrae.org/communities/committees/feedback-on-ashrae-s-culture-of-diversity-and-inclusivity

5 Goals of the Task Group include:

1. Communicate a compelling rationale for diversity and inclusion in engineering, the HVAC&R industry and ASHRAE.
2. Develop an understanding of the diversity profile of those in engineering, the HVAC&R industry and ASHRAE relating to education, training, employment and membership.
3. Understand and remove barriers to diversity and inclusion through programs, education and advocacy.
4. Identify metrics and then measure and report on impact.
5. Lead the way in demonstrating good diversity in practice.

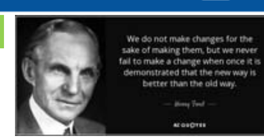
Tim McGinn, Chair | Robin Bryant | Dunstan Macauley | Russell Lavitt | Sheila Hayter | Andres Sepulveda | Tanisha Meyers-Lisle

5

Society Transformation Ad Hoc

Goals of Transformation

- Free the BOD and ExCom for strategic activities
- Remove waste/operating cost
- De-silo ASHRAE and speed decision making
- Push decision-making lower in the organization
- Be market focused
- Expand and amplify our relevance



Transformation Initiatives

- Streamlining organizational structure
- Develop product and services business plan based on market needs and expectations
- Produce market-based digital business plan to distribute ASHRAE technology
- Create LEAN business plan for ASHRAE and industry

6

Nominations Needed!

Committee Nominations

- Due by **mid-February.** Council, RAC, TAC, Standards and Handbook nominations are due **mid-September**
- Speak with your committee ExO if your current appointment ends in June and you wish to be nominated for another committee

ashrae.org/committee-nominations

Honors & Awards Nominations

ASHRAE's awards fall into one of six categories:

- Personal Honors
- Personal Awards for General & Specific Society Activities
- Paper Awards
- Society Awards to Groups or Chapters
- Chapter and Regional Awards

ashrae.org/honorsandawards

Learn about ASHRAE Technical Committees (TCs) at ashrae.org/communities

7

New Global Headquarters

180 Technology Parkway NW
Peachtree Corners, GA 30092

ASHRAE has officially moved into a renovated 66,700 ft² building, originally built in 1978.

Over $10.2M in monetary and in-kind support was received from generous stakeholders to support this renovation project.

PV system design is underway with installation to be completed this spring to drive NZE performance

See the video tour, photos, building technical features and our generous sponsors at ashrae.org/newhq

8

Epidemic Task Force (ETF)

Continues to provide COVID-19 related resources, making ASHRAE a trusted source of critical guidance during the pandemic.

The most visited page on our website: ashrae.org/covid19

Clickable infograph for easy navigation, FAQ's and free resources

ashrae.org/covid19

9

Bylaws Update

Proposed Bylaws change, to be voted on Spring 2021: Change title of 'Member' grade to "Full Member"

ASHRAE Bylaws
Section 2.1 Grades of Membership.
These shall be designated as follows:
(A) Honorary Member,
(B) Presidential Members,
(C) Fellow,
(D) Life Member,
(E) Life Associate Member,
(F) **Full** Member,
(G) Associate Member,
(H) Affiliate Member, and
(I) Student Member.

'Member' grade refers to individuals who have provided necessary education and professional background information to the Society in order to advance from Associate to Member grade.

This proposed Bylaws change would update the title of 'Member' to **'Full Member'.**

ashrae.org/about/governance

10

Membership & Communities

Your Benefits ashrae.org/membership

New Member Benefit Selection
Society Year 2020-2021
Full Dues paying Members and Associate Members will be able to select from the following complimentary annual member benefits starting SY 2020-2021:

- ✓ ASHRAE eLearning Course
- ✓ ASHRAE Standard (PDF)
- ✓ ASHRAE Handbook (PDF)

Members can opt to include a Handbook Online subscription or printed copy of the Handbook for an additional fee.

50,000+ Society Members including 5200+ Student Members

15 Regions with 198 Chapters and 400+ Active Student Branches

Connect-A-Colleague
Quickly invite peers to join ASHRAE and participate in committees using a pre-written email invitation at **ashrae.org/connect**

Your Community ashrae.org/communities

11

ASHRAE Support

Research Promotion (RP)

The Research Promotion campaign supports ASHRAE Research, Education, YEA programs, Scholarships, Endowed Funds, and the RP General Fund.

Thank You to all the **donors and volunteers** for your support during this challenging year.

Society Year 2019-2020 total raised: **$2,117,677**

- $1,635,596 in contributions for Research
- $277,720 for ASHRAE Foundation
- $170,596 for Scholarships
- $33,765 for General Fund, YEA, and Education

ASHRAE Foundation Grants & Scholarships

The ASHRAE Foundation is an endowed trust that provides funding for professional development and research programs, supplies qualified engineering students with much needed scholarship assistance, and provides grants to help support the Society's vital work.

30 Society Scholarships totaling $167,000

30 Chapter-Awarded Scholarships totaling $56,000

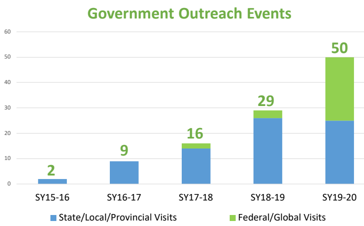
Donate, Volunteer, Apply, and Learn More at ashrae.org/support

12

Government Affairs

ASHRAE **Government Affairs** program works to **establish ASHRAE as a leading source of trusted expertise for policy-makers** in the development of legislation and regulations affecting the public and HVAC&R industry.

- **Government Affairs Update** bi-weekly newsletter provides updates on government activities. Subscribe online or by emailing GovAffairs@ashrae.org.
- **Government Outreach Events** connecting ASHRAE volunteers with policy makers.
- Briefings & Testimony, Regulatory Meetings, Hearings, and Comments.
- **Letters** related to public policy priorities.



Get Involved + Get Resources
ashrae.org/government-affairs

13

ASHRAE Conferences

ASHRAE VIRTUAL WINTER CONFERENCE
February 9-11, 2021

MAR 2021 — **2021 ASHRAE Virtual Design and Construction Conference**
March 8-10, 2021 | Virtual

JUN 2021 — **2021 ASHRAE Annual Conference**
Jun 26–30, 2021 | Phoenix, AZ

SEP 2021 — ***IAQ 2020: Indoor Environmental Quality Performance Approaches***
September 13-15, 2021 | Athens, Greece

ashrae.org/conferences

14

Professional Development

eLearning
Convenient, on-demand courses for individuals or groups.

90+ online courses starting at $42 for members.

Group Rates Available

Updated Course Catalog:
elearningcatalog.ashrae.org

ASHRAE Learning Institute (ALI)
Instructor-led courses in a variety of formats.

New **Virtual HVAC Design Courses**
Live, Instructor-led
- Level I – Essentials
- Level II – Applications

New **2021 Instructor-led Online Series**
ashrae.org/onlinecourses

Courses Available for ASHRAE Chapter, and In-Company Presentations.

Certification
Validate and promote your expertise via **online examination and digital badging:**

Building Design
- Energy Modeling (BEMP)
- Healthcare Facility Design (HFDP)
- High-Performance Building Design (HBDP)
- HVAC Design(CHD)

Building Performance
- Commissioning (BCxP)
- Energy Assessment (BEAP)

Building Operations
- Operations & Performance Maintenance (OPMP)

ashrae.org/professional-development

15

Publications and Standards

Recently Published items available at ashrae.org/bookstore

Standard 135-2020
BACnet
A Data Communication Protocol for Building Automation and Control Networks

Standard 170-2021
Ventilation of Health Care Facilities
Coming soon!

Guideline 41-2020
Design, Installation and Commissioning of Variable Refrigerant Flow (VRF) Systems

Standard 55-2020
Thermal Environmental Conditions for Human Occupancy

Standard 90.1 User's Manual
(based on ANSI/ASHRAE/IES Standard 90.1-2019)

16

Resources

ASHRAE Technology Portal	A one-stop location for ASHRAE papers, articles, reports, Handbook PDFs, and seminar recordings.
Online Standards Database	Allows access to public review drafts for standards, guidelines, and addenda to submit comments, to do online balloting, and to submit proposals to standards and guidelines.
Zero Energy Advanced Energy Design Guides (AEDG)	For offices and K-12 schools are available for free download. **Multifamily AEDG available early 2021.**
Science and Technology for the Built Environment	Provides free online access to archival research publication offering comprehensive reporting of original research.
ASHRAE Technical Apps	Deliver mobile design, calculation, and analysis tools to the palm of your hand.
Free Technical Resources	Offer downloads of a variety of well-known resources to everyone.
ASHRAE 365	Free year-round updates on all things ASHRAE.

Find these resources and many more at ashrae.org

17

ASHRAE Individual Bio Report

1a Basic Data

Mr Walter N Vernon

ASHRAE# XXXXXXX

Business	Primary	Home	Primary
Mr Walter N Vernon Mazzetti 220 Montgomery St Ste 650 San Francisco, CA 94104-3491	Yes		
XXXXXXXXXXX(Fax)	Yes		
XXXXXXXXXXX(Business)	Yes		No
XXXXXXXXXX (Business)	Yes		

Date Bio Revised

02/26/2020

1b Membership Information

Original Election Date	Current Grade	Date	Chapter Membership
01/01/2005	Member	12/10/2004	GOLDEN GATE

Membership History

Grade	Start Date	End Date
Member	12/10/2004	

2 Educational Record

Institution	Degree	Course	Date
U. C. Berkeley	M.B.A.		
Vanderbilt University	BS Math		
University of San Francisco	J.D.		
Vanderbilt University	Bachelor Engineering		

3a Professional Registrations

Country	Type	License	State	Year Issued
UNITED STATES	PE	957	GU	2007
UNITED STATES	PE	E13790	CA	2007
UNITED STATES	PE	18125	CT	2008
UNITED STATES	PE	39763	MI	2008
UNITED STATES	PE	12938	IA	2007
UNITED STATES	PE	22564	MN	2008
UNITED STATES	PE	29228	CO	2009
UNITED STATES	PE	E7926	NE	2008
UNITED STATES	PE	9532	ME	2007
UNITED STATES	PE	25770	MO	2008
UNITED STATES	PE	19510	AL	2007
UNITED STATES	PE	27144	AZ	2008
UNITED STATES	PE	7500	HI	2008

ASHRAE Individual Bio Report

3b ASHRAE Certifications

4 Professional Experience

Employer	Title	From	To	Job Focus / Description
Mazzetti	PRESIDENT	03/16/1992		

5a Society Participation

5b1 Chapter & Region

5b2 Section

5c Technical/Standards

Standard Project Committee Officer and/or Membership (SPC, SSPC, GPC, SGPC)

Committee	Position	From	To
T-STDS-SSPC 189.3	VICE-CHAIR; PCVM-DESIGNER	07/02/2020	06/30/2022
T-STDS-SSPC 189.3	VICE-CHAIR; DESIGNER	10/04/2017	07/01/2020
T-STDS-SSPC 188 (Gdl 12)	OR/ASHE; PCVM-USER	10/14/2015	06/30/2017
T-STDS-SPC 188 (Gdl 12)	OR/ASHE; PCVM-USER	09/27/2013	06/30/2015
T-STDS-SSPC 189.3 (formerly SPC 189.2)X	VICE CHAIR; PCVM-DESIGNER	07/01/2010	10/03/2017
T-STDS-SSPC 189.3 (formerly SPC 189.2)X	PCVM-DESIGNER	07/01/2008	06/30/2010

Technical Committee (TC) and Task Groups (TG) Officer and/or Membership

Committee	Position	From	To
T-TAC-TC09.06	Member	07/01/2018	06/30/2022
T-TAC-TC09.06	Corresponding Member	07/01/2011	06/30/2018

5d ASHRAE Meeting Activities

5e Other ASHRAE Meeting Activities (Speaker, Lecturer, etc.)

Event	Role	Date

ASHRAE Individual Bio Report

6 Membership and Activities In Other Societies Or Trade Associations

Name	Grade	Years
AIA Committee on Architecture for Health	Member	
American College of Healthcare Executives		
American Hospital Association, Health Information Management System Society		
American Society for Healthcare Engineering		
California Hospital Building Safety Board		
FGI Guidelines Revision Committee for HC Construction		
Health Information Management System Society	Member	
Institute of Electrical and Electronics Engineers		
NFPA 99 Task Force of the Advocacy Management Committee, American Society for Healthcare Engineering	Chairman	
NFPA 99, Electrical Systems Committee	Principal Member	
Practice Greenhealth	Board Member	
Society of Professionals in Healthcare		
US Green Building Council		

7 Broad and Technical Interests

Broad Areas of Interest

ENERGY RECOVERY

Technical Areas of Interest

Mission Critical Facility Design

Educational Facility Design

Healthcare Facility Design

Building Automation

Building Operation & Maintenance

Controls, Instruments, Measurement

Heat Transfer and Fluid Flow

8a ASHRAE Awards

8b Other Honors and Awards

9 Publications

Date	Title	Publication	Type
04/01/2006	**Healthy IAQ, Healthy Patients**	Environmental Design +Construction	Author
03/01/2006	**Lessons Learned from the Green Guide for Health Care Pilot**	Healthcare Design	Author

ASHRAE Individual Bio Report

10 Patents

11 Projects

12 Civic, Charitable and Military Service

13 Languages

14 Biographical Record

ASHRAE Individual Bio Report

Additional Biographical Information

Walt Vernon is the CEO of Mazzetti, a national consulting and engineering firm headquartered in San Francisco. Walt has degrees in Philosophy, Mathematics, Electrical Engineering, Business, and Law. He has been working with healthcare clients to plan, design, and operate healthcare facilities around the world for more than 25 years. Walt Chairs the NFPA 99 Electrical Systems Technical Committee. Walt is the former Electrical Engineer for the California Hospital Building Safety Board, where he authored the nation's first Green Healthcare Construction Code. Walt served
as one of three co-coordinators for the Green Guide for Healthcare, the nation's first Green Healthcare rating system. Walt co-authored the IEEE/ANSI White Book, the international standard for Electrical Systems in Healthcare Facilities. Walt co-chairs the ASHRAE 189.3 committee which is currently writing a model national green building code for healthcare facilities. Walt chairs the Research and Development Committee for the Facilities Guideline Institute, the body that writes the Guidelines for Healthcare Construction, the model licensing code for most states in the country. In that role, he is leading an industry effort to create a new vision for the future of healthcare facilities and for their licensing. Walt
is the Principal Author for the WHO Book, Healthcare in the Green Economy, a prescription for the global healthcare sector's response to climate challenges. Walt is a former board member of Healthcare Without Harm and Practice Greenhealth. Walt is leading the team developing the American Hospital Association's Sustainability Roadmap. Walt co-led one of the two teams that won Kaiser's international Small Hospital Big Idea competition, which created a vision for the hospital of the future. Walt is a frequent national and international speaker on the future of healthcare facilities, and, particularly, on their appropriate response to climate.
Walt holds a BE and BS in Electrical Engineering and Mathematics/Philosophy, respectively, from Vanderbilt University, an MBA from the University of California, Berkeley, and a JD from the University of San Francisco.

Environmental Health Committee (EHC) recommends the following members to the Infectious Aerosols PD Committee:

- Bill Bahnfleth, Pennsylvania State University – General (bio)
- Jamechia Hoyle, National Center for Biomedical Research & Training – Public (bio)
- Paul Jensen, retired – Public (bio)
- Kishor Khankari, AnSight - General (bio)
- Yuguo Li, Hong Long University – General (bio)
- Linsey Marr, Virginia Tech - General (bio)
- Jovan Pantelic, UC Berkeley – General (bio)
- Nathalie Robbel, WHO - Public (bio)
- Chandra Sekhar, National University of Singapore – General (bio)
- Dave Sine, Veterans Administration – User (bio)
- Wayne Thomann, Duke University – User (bio)

BACKGROUND: A revision to the Infectious Aerosols PD was authorized by BOD ExCom at the 2020 Virtual Annual Meeting. Mr. Walt Vernon was approved by EHC as chair. The members represent various fields, outside experts, and relevant ASHRAE committees. ASHRAE bios for ASHRAE members and CV's for non-members are attached. The World Health Organization (WHO) has expressed a strong interest in participating and co-publishing the position document.

The following advisory committee has been identified as well. These members would serve as non-voting members on the committee:

- Jim Crabb, Mazzetti
- Travis English, Kaiser Permanente
- Larry Schoen, Schoen Engineering
- Paul Supan, American Dental Association
- Don Weekes, CIH, Retired
- Stephanie Taylor, Taylor Healthcare Consulting
- More WHO representatives

ASHRAE Individual Bio Report

1a Basic Data

Dr Pawel Wargocki

ASHRAE# XXXXXX

Business	Primary	Home	Primary
Dr Pawel Wargocki DTU Civil Engineering-Tech Univ of Denmark Nils Koppels Alle, Building 402 DTU Civil Engineering Kongens Lyngby DK-2800 DENMARK	Yes		
Dr Pawel Wargocki DTU Civil Engineering-Tech Univ of Denmark Nils Koppels Alle Building 402 Kongens Lyngby 2800 DENMARK	No		
XXXXXXX(Fax)	Yes		
XXXXXXXXX(Business)	Yes		No
XXXXXXXXX(Business)	Yes		

Date Bio Revised

02/11/2020

1b Membership Information

Original Election Date	Current Grade	Date	Chapter Membership
03/01/2012	Member	01/09/2020	REGION XIV - OTHER

Membership History

Grade	Start Date	End Date
Member	01/09/2020	
Associate	02/09/2012	01/08/2020

2 Educational Record

Institution	Degree	Course	Date
Tehnical University of Denmark	Ph. D.		1998
Warsaw University of Technology	M. Sc.		1990

3a Professional Registrations

3b ASHRAE Certifications

4 Professional Experience

Employer	Title	From	To	Job Focus / Description
Technical University of Denmark	PROFESSOR/INSTRUCTOR	09/01/1998		RESEARCH
Warsaw University of Technology	ASSOCIATE	06/01/1990	12/31/1994	TEACHING

ASHRAE Individual Bio Report

5a Society Participation

Board of Directors/Society

Committee	Position	From	To
RESEARCH ADMINISTRATION COMMITTEE	RESEARCH LIAISON 2.0 RPS	07/01/2015	06/30/2019
ENVIRONMENTAL HEALTH COMMITTEE	Consultant	07/01/2014	06/30/2015
ENVIRONMENTAL HEALTH COMMITTEE	Chair	07/01/2013	06/30/2014
ENVIRONMENTAL HEALTH COMMITTEE	Vice Chair	07/01/2012	06/30/2013
ENVIRONMENTAL HEALTH COMMITTEE	Member	07/01/2009	06/30/2012

Society, General or Ad Hoc Committee Officer and/or Membership

Committee	Position	From	To
ASHRAE Research Advisory Panel	Member	08/01/2019	
Indoor Quality Alliance Ad Hoc Committee	Member	07/01/2014	06/30/2016
A-Indoor Environmental Quality Alliance Ad Hoc Committee	Member	07/29/2013	06/30/2014
TECHNOLOGY COUNCIL	NON-VOTING MEMBER/ENVIRONMENTAL HEALTH CHAIR	07/01/2013	06/30/2014
TECHNOLOGY COUNCIL	NON-VOTING MEMBER/ENVIRONMENTAL HEALTH VICE CHAIR	07/01/2012	06/30/2013
IAQ 2013 Steering Committee	Member	01/01/2011	10/31/2013

5b1 Chapter & Region

5b2 Section

5c Technical/Standards

Standard Project Committee Officer and/or Membership (SPC, SSPC, GPC, SGPC)

Committee	Position	From	To
T-STDS-SSPC 62.1 (Gdl 42)	CONSULTANT; RESEARCH AND EDUCATION SUBCOMMITTEE	02/01/2018	06/30/2019
T-STDS-SSPC 62.1 (Gdl 42)	CONSULTANT; RESEARCH AND EDUCATION SUBCOMMITTEE	02/01/2016	01/31/2018
T-STDS-SSPC 62.1 (Gdl 42)	CONSULTANT; ADMINISTRATION SUBCOMMITTEE	10/14/2015	01/31/2016
T-STDS-SSPC 62.1 (Gdl 42)	PCVM-GENERAL; ADMINISTRATION SUBCOMMITTEE	07/03/2014	10/13/2015
T-STDS-SGPC 10	NVM-GENERAL	10/01/2013	06/30/2017
T-STDS-SSPC 62.1 (Gdl 42)	PCVM-GENERAL; ADMINISTRATION SUBCOMMITTEE	07/01/2011	07/02/2014

ASHRAE Individual Bio Report

Technical Committee (TC) and Task Groups (TG) Officer and/or Membership

Committee	Position	From	To
T-TAC-TC02.10	Research Liaison	07/01/2018	
IAQ PD Committee	Member	12/13/2017	
T-TAC-TC02.01	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.02	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.03	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.04	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.05	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.06	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.07	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.08	Research Liaison	07/01/2015	06/30/2019
T-TAC-TC02.09	Research Liaison	07/01/2015	06/30/2019
T-TAC-TG2.HVAC	Research Liaison	07/01/2015	06/30/2018
PLANNING SUBCOMMITTEE	Member	07/01/2012	06/30/2013
T-TAC-TC02.01	Corresponding Member	07/01/2012	
Air Filtrartion and Cleaning PD Committee	CHAIR	01/03/2012	
T-TAC-MTG.EEC	MEMBER - EHC	07/01/2011	06/30/2015

5d ASHRAE Meeting Activities

5e Other ASHRAE Meeting Activities (Speaker, Lecturer, etc.)

Event	Role	Date

6 Membership and Activities In Other Societies Or Trade Associations

7 Broad and Technical Interests

Broad Areas of Interest

INDOOR ENVIRONMENTAL QUALITY

Technical Areas of Interest

Physiology

Humidifying & Dehumidifying Equipment

Moisture Management & Control

Air Cleaning & Odor Control

Ventilation Requirements & Infiltration

IAQ Procedures

Commissioning & Testing/Balancing

Educational Facility Design

ASHRAE Individual Bio Report

Residential & Small Building Applications

Building Design & Load Calculations

Controls, Instruments, Measurement

Thermodynamics & Psychrometrics

8a ASHRAE Awards

Award

2017 - Distinguished Service Award

2018 - Environmental Health Award

8b Other Honors and Awards

Award	Organization	Year
Member of International Academy of Indoor Air Sciences	International Academy of Indoor Air Sciences	2009
Rockwool Award for Young Researchers	Rockwool	2005
Ralph G. Nevins Physiology and Human Environment Award	ASHRAE	2002
Best Paper Award for paper published in Indoor Air journal 1999-2001	Indoor Air Journal	2002
SCANVAC Award for Young Researchers	SCANVAC	2001
Yaglou Award	International Academy of Indoor Air Sciences	2001
P. Gorm-Petersens's Award for best Ph.D.-thesis in 1999 at the Technical University of Denmark	Technical University of Denmark	2000
Polish Ministry of Buildings Award for outstanding M.Sc. Thesis	Warsaw University of Technology, Poland	1990

9 Publications

Number of Books: 11

Number of Papers: 27

Number of Articles: 85

Date	Title	Publication	Type
	Indoor environment, productivity in offices	ASHRAE IAQ Applications	Co-Author
	The effects of outdoor air supply rate and supply air filter condition in classrooms on the performance of schoolwork by children (1257-RP)	HVAC&R Research	Author
	Strategy for good perceived air quality in sustainable buildings	Proc CLIMA 2010	Co-Author
	The Effect of Using Low-Polluting Materials on Air Quality and Energy Consumption in an Office	Proc CLIMA 2001	Author
	The effects of moderately raised classroom temperatures and classroom ventilation rate on the performance of schoolwork by children (1257-RP)	HVAC&R Research	Author
	Effects of HVAC on Student Performance	ASHRAE J	Author
	Ventilation and health in nonindustrial environments. Report from a European multidisciplinary scientific consensus meeting	Proc CLIMA 2001	Author

ASHRAE Individual Bio Report

Effect of streamer plasma air purifier on perceived air quality, sbs symptoms and performance of office work	Proc CLIMA 2013	Co-Author
How one should perform sensory measurements of the perceived air quality	Proc CLIMA 2010	Author
A European project SysPAQ	Proc CLIMA 2007	Co-Author
The effects of electrostatic filtration and supply air filter condition in classrooms on the performance of schoolwork by children	HVAC&R Research	Author
Effect of using low-polluting building materials and increasing ventilation on perceived indoor air quality	Proc CLIMA 2007	Author
Simulations of the potential revenue from investment in improved indoor air quality in an office building	ASHRAE Transactions	Author
Ventilation System Type and the Resulting Classroom Temperature and Air Quality during Non-Heating Season	Proc CLIMA 2013	Co-Author
IAQ Applications: Filtration and Air Cleaning	ASHRAE J	Author
How indoor environment affects performance	ASHRAE J	Co-Author
The effects of outdoor air supply rates in classrooms on the performance of schoolwork by children	Proc CLIMA 2005	Author

10 Patents

Number of Patents: 0

11 Projects

Name	Year	Role	Significance
EFFECTIVE ENERGY-EFFICIENT CLASSROOM VENTILATION FOR TEMPERATE ZONES (ASHRAE 1624 TRP)	2014-2017	co-PI	significant

ASHRAE Individual Bio Report

Indoor Environmental Effects On The Performance Of School Work By Children (1257 TRP)	2004-2007	PI	Significant

12 Civic, Charitable and Military Service

13 Languages

14 Biographical Record

Additional Biographical Information

coChair Indoor Air 2008 Conference

Seminar Speaker, Denver 2005, New York 2014, St. Louis 2016

Seminar Chair, Dallas 2013

ASHRAE Position Document on Filtration and Air Cleaning

Approved by ASHRAE Board of Directors
January 29, 2015

Reaffirmed by Technology Council
January 13, 2018

Expires January 23,
2021

ASHRAE
1791 Tullie Circle, NE • Atlanta, Georgia 30329-2305
404-636-8400 • fax: 404-321-5478 • www.ashrae.org

COMMITTEE ROSTER

The ASHRAE Position Document on Filtration and Air Cleaning was developed by the Society's Filtration and Air Cleaning Position Document Committee formed on January 6, 2012, with Pawel Wargocki as its chair.

Pawel Wargocki, *Chair*
Technical University of Denmark
Kongens Lyngby, Denmark

Thomas H. Kuehn
University of Minnesota
Minneapolis, MN

H.E. Barney Burroughs
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HISTORY OF REVISION/REAFFIRMATION/WITHDRAWAL DATES

The following summarizes this document's revision, reaffirmation, or withdrawal dates:

01/29/2015—BOD approves Position Document titled Filtration and Air Cleaning

01/23/2018 - Technology Council approves reaffirmation of Filtration and Air Cleaning position document

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

Note: ASHRAE position documents are approved by the Board of Directors and express the views of the Society on a specific issue. The purpose of these documents is to 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. A related purpose is also to serve as an educational tool clarifying ASHRAE's position for its members and professionals, in general, advancing the arts and sciences of HVAC&R.

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ASHRAE Position Document on Filtration and Air Cleaning

ABSTRACT

Filtration and air cleaning are used to improve indoor air quality and occasionally to enable a reduction in rates of outdoor air ventilation. This Position Document addresses the health consequences of filtration and air cleaning. Data from refereed archival literature are used to form summary statements on performance as well as the positions with respect to specific technologies. One key statement is that, at present, there is only significant evidence of health benefits for porous media particle filtration systems. For a few other technologies, there is evidence to suggest health benefits, but this evidence is not sufficient to formulate firm conclusions. A key position is that filtration and air-cleaning technologies are not recommended for use if they produce significant amounts of contaminants that are known or expected to be harmful for health. Finally, it is stated that there are limited data documenting the effectiveness of gas-phase air cleaning as an alternative to ventilation. ASHRAE should continue supporting research and standardization of contemporary filtration and air-cleaning technologies and should focus on performance testing, maintenance procedures, and development of new innovative technologies.

EXECUTIVE SUMMARY

ASHRAE needs to address heating-, ventilation-, and air-conditioning- (HVAC) related technologies that change exposures to airborne contaminants harmful for humans. As part of ASHRAE's mission, it is imperative to assess the effectiveness of HVAC technologies in reducing exposures so that the risks for harmful effects on health and comfort are minimized and to establish and promote the Society's positions that will guide ASHRAE membership and the public in technology selection and use. This need applies to filtration and air-cleaning technologies because they traditionally are part of the HVAC system, their use is included and/or required in many guidelines and ventilation standards published by ASHRAE, and they are addressed by technical committees within ASHRAE. Evaluation and guidance are also needed because of the increasing number and variety of filtration and air-cleaning alternatives available on the market and because filtration and air cleaning are considered attractive alternatives to outdoor air ventilation by providing exposure control with less energy use.

Various filtration and air-cleaning technologies are available, depending on the type of contaminants removed and the principle of contaminant removal. This Position Document briefly characterizes these technologies and their applications. The focus is to summarize and examine the existing archival literature describing the direct effects of application of these technologies in public and residential buildings (excluding health-care facilities) on the health of building occupants. Based on the accumulated information, statements on the effectiveness and use of different technologies are proposed and are briefly summarized as follows:

- Mechanical filters have been shown to reduce significantly indoor concentrations of airborne particles. Modest empirical evidence shows that their use will have positive effects on health.
- Electronic filters have been shown to range from being relatively ineffective to very effective at removing indoor airborne particles. Studies of ionizers have shown results ranging from no benefit to some benefit for acute health symptoms.
- There are some sorbent air cleaners that have been shown to substantially reduce the concentrations of gaseous contaminants. There are minimal empirical data that indicate the effects of sorbent air cleaners on health.
- Photocatalytic oxidation technologies have been shown to remove harmful contaminants, to be ineffective in removing contaminants, and/or to generate harmful contaminants during the air-cleaning process. There are no data on how their use affects health.
- Ultraviolet germicidal energy (UV-C) has been shown to inactivate viruses, bacteria, and fungi. A few studies have shown that air-cleaning technologies using UV-C disinfection (also termed *ultraviolet germicidal irradiation* [UVGI]) produce beneficial health effects. There are also studies that have failed to detect health benefits.
- Many types of packaged stand-alone air cleaners using combinations of air-cleaning technologies are available. Scientific data addressing the effects of these air cleaners on health are sparse and inconclusive.
- Negative health effects arise from exposure to ozone and its reaction products. Consequently, devices that use the reactivity of ozone for cleaning the air should not be used in occupied spaces. Extreme caution is warranted when using devices in which ozone is not used for the purpose of air cleaning but is emitted unintentionally during the air-cleaning process as a by-product of their operation.

- There has been much research done on ventilation providing the solution to contamination by dilution, while the body of research on using air cleaning as an effective, energy-saving alternative to ventilation has not been equally large, especially as regards gas-phase air cleaning. Still it should be noted that the information on the effective use of air cleaning as an alternative to ventilation is growing. Limited data exist documenting the effectiveness of air cleaning as an alternative to ventilation. This applies in particular to gas-phase air cleaning. All filtration and air-cleaning technologies should be accompanied by data documenting their performance in removal of contaminants. These data should be based on established industry test standards or third-party evaluations.

The Position Document advocates that ASHRAE lead efforts in research and standardization of filtration and air cleaning. First priority should be given to advancing methods for testing performance of filtration and air-cleaning technologies, in particular the emerging technologies. Second priority should be given to maintenance procedures of filtration and air-cleaning technologies.

1. THE ISSUE

1.1 Justification of Need

Air in buildings contains various classes of contaminants: particulate matter (some biological in origin), gases, and vapors. Sources for many of these contaminants may be located either indoors (building components, occupants, and occupant activities), outdoors, or both indoors and outdoors. Filtration and air-cleaning technologies are used to reduce exposures to these contaminants in buildings by intentionally removing them from the air. The contaminants are either physically removed or participate in chemical reactions (i.e., are transformed with the intent of producing innocuous compounds). Different filtration and air-cleaning technologies are in use, depending on the class of contaminants that needs to be removed.

Filtration and air cleaning are methods for reducing exposures to contaminants indoors and thus improving indoor air quality. These methods may create viable alternatives and/or supplements to other methods for exposure reduction by supporting dilution via outdoor air ventilation by ensuring that the outdoor and/or recirculated air supplied indoors by HVAC systems is less contaminates and by improving ventilation efficacy by removing contaminants that have an indoor origin. Because these methods reduce concentrations, and thus, exposures to contaminants, many conclude that their application allows reducing outdoor airflow levels for ventilation; this belief is especially valid when outdoor air is heavily contaminated or is burdened with high humidity and thermal loads and when these technologies can remove contaminants at a lower cost than through ventilation alone.

Abundant published data show the effectiveness of different filtration and air-cleaning technologies in removing contaminants from indoors and outdoors. However, few studies document the direct effects of these technologies on health and their long-term performance, as well as their potential limitations and shortcomings. A recent comprehensive review (Zhang et al., 2011) reaffirms these observations.

1.2 Purpose and Scope

This document informs ASHRAE membership and the public about the positive, benign, or negative effects of filtration and air-cleaning technologies on health. Health effects, in the context of this position document, are understood as the effects on biomarkers, quality of life, physiological impact, symptoms, clinical outcomes, or mortality (American Thoracic Society 2000).

The document briefly characterizes the major categories of filtration and air-cleaning technologies, and their applications for removing contaminants from outdoor air brought into buildings and/or indoor air. The air-cleaning effects of plants and new air-cleaning technologies, for which there is very limited scientific and technical literature, are not considered.

The archival studies are reviewed to examine measurable health effects associated with the application of various filtration and air-cleaning technologies in public and residential buildings (excluding health-care facilities) and the extent to which cleaning and filtration technologies can offset ventilation with outdoor air for acceptable indoor air quality.

This document also describes the role and health implications of optimal use of air cleaners and the maintenance and replacement of air-cleaning media. The health issues related to disposal of filters and the elements of air cleaners are not considered.

Packaged stand-alone air cleaners using one or multiple technologies and air-cleaning and filtration systems integrated in the ventilation systems are considered as well as technologies available to and used by commercial or residential consumers.

2. BACKGROUND

2.1 Mechanical and Electronic Air Filters

2.1.1 Principles of Efficiency and Use. Mechanical filters use media with porous structures that contain fibers or stretched membrane material in a variety of fiber sizes, densities, and media extension configurations to remove particles from airstreams. A portion of the particles in the air entering a filter attaches to the media and is removed from the air as it passes through the filter. Removal occurs primarily through particle impaction, interception, and Brownian motion/diffusion, depending on particle size. Some filters have a static electrical charge applied to the media to increase particle removal.

Electronic filters include a wide variety of electrically connected air-cleaning devices that are designed to remove particles from airstreams. Removal typically occurs by electrically charging the particles using corona wires or through generation of ions (e.g., using pin ionizers) and by collecting the particles on oppositely charged deposition plates (precipitators) or by the particles' enhanced removal to a conventional media filter or to room surfaces.

The fraction of particles removed from air passing through the filter is termed *particle removal efficiency* or simply *filter efficiency* or *single-pass filter efficiency* (e.g., provided by the minimum efficiency reporting value [MERV]). For electronic filters that are portable and self-contained, the rate of particle removal from air passing through the filter is expressed as clean air delivery rate (CADR), which is approximately equal to the product of airflow rate and the contaminant removal efficiency. For most technologies, the lowest particle removal efficiency typically occurs for particles with an aerodynamic diameter of approximately 0.2 or 0.3 μm; the removal efficiency increases above and below this particle size. The efficiency of mechanical and electronic air filters varies with filter design and particle size. The efficiency of electronic air cleaners also depends on how they are maintained.

The overall effectiveness of reducing indoor particle concentrations depends on several factors that are either related or independent of a filtration system such as the following: single-pass particle removal efficiency of the filter, the rate of airflow through the filter, location of the filter, and size of the particles. The latter include outdoor air ventilation rate, rate of deposition to surfaces, and total volume of the indoor space and related air change rate, particularly important for stand-alone (portable) air cleaners (see Section 2.5). Recirculation of indoor air through filters and refiltering blended outdoor air with return air are particularly effective for maximizing filter system effectiveness. Filtering the incoming outdoor air before this air enters the occupied space is effective in reducing indoor air concentrations of outdoor air particles, especially in airtight buildings.

ANSI/ASHRAE Standard 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size* (2012a), provides a method of measuring the particle removal efficiency of particle filters for particles that range in size from 0.3 to 10 μm and provides a scale for ranking filters, based on their particle removal efficiencies, called MERV; similar test methods and ranking scales are also available from other organizations. *Indoor Air Quality Guide: Best Practices for Design, Construction, and Commis-*

sioning (2009a) and Chapter 29 in the 2012 *ASHRAE Handbook—HVAC Systems and Equipment* (2012b) and provide additional information on particle filtration technologies and test methods.

2.1.2 Evidence on Health Effects. An extensive body of epidemiological research indicates that death rates, hospital admissions, and asthma exacerbations, as well as other adverse health effects increase with increased concentrations of particles in outdoor air (e.g., Brunekreef and Forsberg 2005; Delfino et al. 2005; Pope and Dockery 2006). Because much of a person's exposure to outdoor air particles occurs indoors and because this exposure can be reduced by filtration, it is reasonable to expect associated health benefits from particle filtration that is effective in removing particles having outdoor origin.

Published relationships between outdoor air particle concentrations and adverse health effects have been used in models to predict the related health benefits of particle filtration. The resulting papers, reviewed by Fisk (2013), indicate substantial health benefits associated with filtration, with benefits generally proportional to the reduction in total exposure to particles less than 2.5 µm in diameter. The models considered numerous health or health-related outcomes, including mortality, cardiac or respiratory-related emergency room visits or hospital admissions, chronic bronchitis, and asthma exacerbation. Because most of these health outcomes occur in a small portion of the population, very large empirical studies would thus be needed to confirm these predictions, and such studies have not been performed. Two studies found statistically significant improvements with filtration in biomarkers that predict future adverse coronary events (as cited in Fisk 2013), providing some empirical support for the model predictions of health benefits.

Many studies have experimentally investigated whether the use of particle filtration systems in homes reduces self-reported symptoms of allergies or asthma or improves related objectively measured health outcomes such as forced expiratory volume or biomarkers of inflammation in people who are allergic or asthmatic. Most of these studies used stand-alone (portable) fan filter systems incorporating high-efficiency particle air (HEPA) filters that can remove particles with a minimum efficiency of 99.97% for 0.3 µm particles. A few studies investigated whether use of particle filtration systems in offices or schools reduce nonspecific self-reported health symptoms, often called sick-building syndrome (SBS) symptoms, in the general population. The origin of the particles removed was not identified. Most of these studies report reduced indoor air particle concentrations of 20% to 80%, and 50% a typical reported value. Nearly all of the studies used mechanical filters. A recent review on the effects of air filtration (Fisk 2013) considered the recently published literature and the results of prior reviews (IOM 2000; Reisman 2001; McDonald et al. 2002; Wood 2002; Sublett et al. 2010; Sublett 2011). It concluded that particle filtration could be modestly effective in reducing adverse allergy and asthma outcomes, particularly in homes with pets. It also concluded that particle filtration systems that deliver filtered air to the breathing zone of sleeping allergic or asthmatic persons might be more consistently effective in improving health than use of room or whole-house filtration systems. The review additionally concluded that the limited available evidence suggests that particle filtration in buildings (homes, offices and schools) is not very effective in reducing acute health symptoms (SBS symptoms) in persons without asthma and allergies.

Several communicable respiratory diseases are transmitted, in part, by inhalation of small airborne particles containing infectious virus or bacteria produced during coughing, sneezing, singing, and talking. The portion of total disease transmission that occurs via this mechanism is uncertain and debatable. Particle filtration systems can reduce indoor airborne concentrations of these particles by removing them from the airstream but not by inactivating infectious species. Filtration may thereby reduce the incidence of the associated communicable respiratory diseases, provided the airstream transports the particles to the filtration system. The results of modeling suggest that having filters in HVAC systems, relative to having no filters, will substantially decrease the portion of disease transmission caused by these small particles (Azimi and Stephens 2013). However, the model assumptions and inputs have a high level of uncertainty. In addition, experimental data outside of health-care facilities are not available to confirm the predictions; there are no strong studies empirically documenting that filtration reduces respiratory infections in people outside of a health-care environment with highly susceptible patients.

The data on the health consequences of electronic particle air cleaners are sparse, but it is reasonable to expect that electronic air cleaners affect health similarly to mechanical filters of equivalent particle removal performance. There are electronic air cleaners (e.g., ion generators) that produce ozone and thus may cause deleterious health effects, as described in Section 2.6, Ozone-Generating Devices. One class of particle air cleaners, ion generators, has been investigated for its ability to reduce acute health symptoms (SBS symptoms), but the literature is unclear as regards the presence and size of effects on symptoms. Of the eight studies on the subject, there are an approximately equivalent number of findings of a positive effect and of no significant effect (or a negative effect) on one or more SBS symptoms (Hawkins and Barker 1978; Fishman 1981; Laws 1982; Hawkins and Morris 1984; Wyon 1992; Shaughnessy et al. 1994; Rosen and Richardson 1999; Richardson et al. 2001). Variations in sample size, presence or lack of a placebo, and presence of a control group make it difficult to form conclusions that are more definitive.

2.2 Sorbent Air Cleaners

2.2.1 Principles Efficiency, and Use. Sorbent air cleaners involve physical adsorption (physisorption) and chemisorption to remove gaseous contaminants from airstreams. Physisorption is adsorption of gaseous contaminants onto solid porous materials due to Van der Waals forces (nuclear attraction) and condensation in the small pores. This is a reversible process due to relatively weak forces: gases once adsorbed can later desorb back into the airstream. The most common adsorbent used is activated carbon; others include activated aluminas (aluminum oxides), natural and synthetic zeolites in granular form, oxides of silicon, molecular sieves, and various polymers. Chemisorption involves both adsorption and instantaneous irreversible chemical reactions on the sorbent surface to which specific chemical additives or impregnates are added during the manufacturing process to make them more or less specific for individual contaminants or contaminant types (e.g., acid gases). Common adsorbents include activated alumina impregnated with potassium or sodium permanganate and activated carbons impregnated with acidic or basic compounds. Desorption of target contaminants, once adsorbed and chemically reacted, does not occur.

An air-cleaning system using a single gas-phase (or dry-scrubbing) air-filtration medium may not be adequate for the control of multiple contaminants (Muller and England 1994, 1995). Thus, it is common to have a system that uses a combination of both physical and chemisorptive media to provide removal of a wide range of gaseous contaminants.

Adsorbent materials do not adsorb all contaminants equally. The adsorption capacity for nonpolar organics increases with the boiling point, molecular weight, and concentration of the air contaminant. Low molecular weight (less than 50 u [previously termed amu]) and/or highly polar compounds such as formaldehyde, methane, ethanol, etc., will not be readily adsorbed at low concentrations. Compounds with molecular weight >80 u and nonpolar compounds may be preferentially adsorbed over lower molecular weight and polar compounds. In physical adsorption, polar gas molecules are best removed by polar adsorbents, while nonpolar adsorbents are best for removing nonpolar gases (e.g., activated carbon has a nonpolar surface). The initially adsorbed compounds with lower molecular weight and nonpolar compounds may also be desorbed when a higher molecular weight and polar compounds are present through competitive adsorption. A sufficient depth of sorbent bed may re-adsorb some displaced molecules.

Adsorbent-based systems can remove a broad range of contaminants with moderate to high efficiency. The net rate of adsorption depends on the rate at which contaminant molecules reach the surface of the media, the percentage of those making contact, which are adsorbed, and the rate of desorption.

Some evidence is available on the long-term performance of sorbents in commercial buildings in studies that have examined the performance and effectiveness of air-cleaning systems that have been in continuous use for up to 30 years (Bayer et al. 2009; Lamping and Muller 2009; Burroughs et al. 2013). Relatively accurate estimates of sorbent lifetimes can be obtained when target contaminants are identified and by using their known or expected concentrations in air and the individual removal capacities for each (Muller 2012). Actual sorbent life may be determined by taking periodic samples for life testing or through direct contaminant monitoring. More often, though, sorbents are replaced based on routine maintenance cycles or fiscal considerations. Although there exist physisorbents that may be regenerated, this is not economically viable for the amounts typically contained in commercial HVAC systems and portable air cleaners; thus, they need to be periodically replaced.

Other details regarding removal of gaseous air contaminants can be found in *ASHRAE Handbook—HVAC Applications*, Chapter 45, Control of Gaseous Indoor Air Contaminants (2011) and in *ASHRAE Handbook—Fundamentals*, Chapter 11, Air Contaminants (2013a).

2.2.2 Evidence on Health Effects. At present, almost no empirical data are available to enable drawing conclusions about the health benefits of using sorbents in typical buildings, other than anecdotal data describing ancillary benefits of air cleaning on elementary school studies and human embryos (Cohen et al. 1997; Hall et al. 1998; Lamping et al. 2009).

There are, on the other hand, data from laboratory studies that investigated the effects of sorbent air cleaning on initial perceptions of air quality immediately upon entering a laboratory or upon smelling air drawn from a test system (i.e., on perceptions of unadapted individuals, such as visitors to a space, and not on perceptions of adapted persons, such as occupants staying for an extended time in a space) (e.g., Shaughnessy et al. 1994; Fang et al. 2008; Bekö et al. 2008, 2009). These studies showed significantly improved ratings of acceptability or satisfaction with air quality and odor intensities with sorbents. Although perception of air quality comfort is not a health outcome, it may be considered an indicator of a potential subsequent effects of exposures on health.

2.3 Air Cleaners Using Photocatalytic Oxidation

2.3.1 Principles Efficiency and Use. *Photocatalytic oxidation* (PCO) is defined as a light-mediated, redox reaction of gases and biological particles adsorbed on the surface of a solid pure or doped metal oxide semiconductor material or photocatalyst. The most common photocatalyst is TiO_2 (titanium dioxide), while zinc oxide (ZnO), tungsten trioxide (WO_3), zirconium dioxide (ZrO_2),cadmium sulfide (CdS), and iron (III) (Fe(III)-doped TiO_2), among others, are also used. Dopants (e.g., iron [Fe], platinum [Pt], silver [Ag]) can have a beneficial effect on the performance of the metal oxide photocatalyst. The photocatalyst generates oxygen species (or reactive oxygen species [ROS]) that remain surface-bound when exposed to light of particular wavelengths in the ultraviolet (UV) range. The oxygen species are highly reactive with adsorbed gases and biological particles. A variety of UV light sources can be used in PCO, including black lights (UV-A: long-wave; 400 to 315 nm), germicidal lamps (UV-C: short-wave; 280 to 200 nm), and lamps that generate ozone (vacuum UV [UV-V]: under 200 nm). Under reaction conditions allowing for deep oxidation (referred to as mineralization), carbon, hydrogen, and oxygen atoms in the reacting species are converted completely via chemical reaction to water vapor and carbon dioxide. In case the conditions do not promote deep oxidation, for example, due to insufficient residence time because of increased airflow through reactor or the presence of halogenated compounds, PCO can produce intermediate species (by-products) that remain bound to the surface of the photocatalyst or desorb and become airborne.

Nearly all organic, gaseous indoor air contaminants and microbes are subject to PCO decomposition (e.g., Zhang et al. 2011; Dalrymple et al. 2010). The efficiency of catalytic oxidizers depends partially on the functional group of contaminants passing through the PCO device. Higher efficiency is observed for oxygenated compounds such as alcohols, ketones, and some aldehydes; intermediate efficiency for aromatics; and lower efficiencies for chlorocarbons. The PCO conversion rates (or fraction of contaminant removed in a single pass) vary depending on the contaminant and the system design from 0% to nearly 100%, with longer residence times needed to achieve higher (single-pass) efficiencies. Efficiencies of PCO air cleaners and by-products formed by them depend on the design of the device, the indoor air setting (e.g., contaminant composition, relative humidity, temperature) in which they are used, and how the device is maintained.

A systematic parametric evaluation of several performance variables was reported for two styles of PCO air filters: TiO_2 coated on fiberglass fibers (TiO_2/FGFs) and TiO_2 coated on carbon cloth fibers (TiO_2/CCFs) (Zhong et al. 2013). The contaminant destruction rates varied with contaminant class and type of UV source, while formation of by-products correlated with PCO reaction mechanisms for each VOC.

The advantages of PCO are the relatively low pressure drop, ability to treat a wide variety of compounds, and theoretically long life cycle of the reactive process (the self-cleaning or regenerating feature of a photocatalyst). The disadvantages include the lamp energy, lamp replacement costs, and the likelihood of ozone generation depending on lamp source employed (e.g. UV-V lamps ~185 nm produces ozone (O_3). (It has been shown by Ohtani et al. [1992] that irradiation greater than 200 nm and less than 400 nm, in particular UV-C (254 nm), over TiO_2 will decompose O_3. There is also the potential of an incomplete oxidizing process, which produces by-products of reaction that can be more toxic or harmful than the original constituents (e.g., formaldehyde). The catalysts can be contaminated (poisoned) by airborne reagents and/or products of oxidation, which results in reduced or total efficiency failure of the process. Incomplete decomposition of some organic contaminants and net production of formaldehyde, acetaldehyde, formic acid, and acetic acid were shown by Hodgson et al. (2007), who investigated PCO using mixtures of up to 27 organic contaminants in concentrations reflecting the levels typically occurring indoors. Chemisorbent media positioned downstream of a UVPCO air cleaner effectively counteracted the generation of aldehydes due to incomplete oxidation of volatile organic compounds (VOCs) in UVPCO reactors (Hodgson et al. 2007).

Other details about PCO can be found in reviews (e.g., Mo et al. 2009) as well as ASHRAE RP-1134 (Tompkins et al. 2005).

2.3.2 Evidence on Health Effects. No studies are available with respect to the direct health effects associated with the use of PCO air-cleaning equipment in indoor environments. Some studies looked at the effects of PCO on perceived air quality, which, as mentioned above, may be considered as an indicator of potential subsequent effects of exposures on health. These studies found signiicant reductions in the percentages of persons dissatisfied with air quality in rooms contaminated by nonhuman sources of contamination during operation of PCO (Kolarik and Wargocki 2010; Kolarik et al. 2010). However, when the air was contaminated by human bioeffluents, the percentages of persons dissatisfied with air quality significantly increased, suggesting that the air quality was considerably worsened (Kolarik and Wargocki 2010). It was suggested that the alcohols that are a major part of human bioeffluents and their incomplete oxidation are responsible for the observed results.

2.4 Air Cleaners Using Ultraviolet Germicidal Energy (UV-C)

2.4.1 Principles of Efficiency and Use. Ultraviolet (UV-C) disinfection (also called *ultraviolet germicidal irradiation* [UVGI]) is used to degrade organic material and inactivate microorganisms. The system is not a filter; thus, inactive particles remain in the airstream, which, in the case of dead fungal spores, may still cause a negative human response to their integral mycotoxins. The most effective wavelength range for inactivation of microorganisms is between 220 and 300 nm, with peak effectiveness near 265 nm. The typical source of UV-C in commercial and residential air and water systems is low-pressure mercury vapor lamps, which emit mainly near-optimal 253.7 nm. UV-C systems may be installed inside HVAC systems, irradiate air near the ceiling, or be incorporated in a stand-alone (portable) air cleaner.

The effectiveness of a UV-C system to inactivate microorganisms in the air and/or on surfaces has been amply demonstrated; the best results were obtained for the long-term irradiation of downstream coil surfaces to avoid fungal amplification on wet surfaces. Experience suggests that control of a moving airstream does not provide favorable killing rates because of the short dwell time. Under ideal conditions, inactivation and/or killing rates of 90% or higher can be achieved but depend on the following: the type of microbial contaminant; specific species; physical or mechanical factors such as UV-C intensity, exposure/dwell time, lamp distance and placement, and lamp life cycle and cleanliness; air movement and patterns; temperature; relative humidity; and air mixing. Airborne removal is best applied in conjunction with filtration of particles with prefiltration in order to protect lamps and mechanical filtration downstream for microbial particles.

Proposed ASHRAE Standard 185.1 provides a method for testing UV-C lights for use in air-handling units or air ducts to inactivate airborne microorganisms, and ASHRAE Standard 185.2-2014 provides a method of testing ultraviolet lamps for use in HVAC units or air ducts to inactivate microorganisms on irradiated surfaces.

Chapter 17 in the 2012 *ASHRAE Handbook—HVAC Systems and Equipment* (2012b) provides additional information on ultraviolet lamp systems.

2.4.2 Evidence on Health Effects. Several studies have addressed the application of UV-C systems in health-care facilities. Some of these studies show health benefits for highly susceptible patients (Miller et al. 2002; CDC/NIOSH 2009; Memarzadeh et al. 2010). However, there is limited evidence on the direct effects of UV-C on health, particularly when applied outside of health-care settings. Menzies et al. (2003) showed a significant reduction in work-related, self-reported acute health symptoms (SBS symptoms) when the UV-C system in ventilation ducts was irradiating cooling coils and drain pans, compared to when it was powered off. Bernstein et al. (2006) irradiated particles (not the cooling coils or drain pans) using UV-C systems in air moving through the ventilation ducts of homes of mold-sensitized, allergic children. Operation of UV-C, relative to a placebo system containing a blue light produced significant alleviation of several asthma outcomes. Upper-room air UV-C systems applied in studies in schools, military barracks, and homeless shelters provide inconsistent effects on tuberculosis, measles, influenza, and common colds (Kowalski 2009).

Fungal contamination found in ventilation systems may contribute to fungal infections in individuals with compromised immune systems, may release contaminants to occupied spaces (Ahearn et al. 1997; Ezeonu et al. 1994; Levetin et al. 2001; Mahoney et al. 1979; Mendell and Smith 1990; Samson 1985), and may possibly contribute to SBS symptoms and other building-related diseases, such as hypersensitivity pneumonitis, allergic rhinitis, and asthma exacerbation (Burge 1990; Lacey 1991; Levetin 1985). UV-C has been shown to be effective in reduction of microbial and endotoxin agents (Menzies et al. 2003), which can breed and accumulate in ventilation systems, especially where condensation of water vapor occurs; however, no direct evidence of health benefits exists other than the study cited above (Menzies et al. 2003).

UV-C systems have been shown to reduce tuberculosis infection in guinea pigs housed in cages ventilated with air drawn from tuberculosis wards (Riley et al. 1957, 1962; Escombe et al. 2009). In the laboratory studies, UV-C has been effective in removing bacterial aerosols and viral aerosols (Xu et al. 2003). To this end, UV-C for upper air, in-duct, and in-room systems was named by ASHRAE's 2014 *Position Document on Airborne Infectious Diseases* as among the two highest research priorities for developing engineering control to reduce infectious disease transmission (ASHRAE 2014b).

2.5 Packaged Air Cleaners Using Multiple Technologies

Many air-cleaning devices use a combination of filters (i.e., particle air-cleaning technologies and gas-phase air-cleaning technologies). The devices are often stand-alone (portable), incorporate a fan, and are intended for residential use. These devices are frequently called *air purifiers* or *clean-air delivery (CAD) devices*, but many other names are used as well.

Many packaged air cleaners using multiple technologies are tested using the protocol of the Association of Home Appliance Manufacturers (AHAM) (AHAM 2013) to determine performance reported as the clean-air delivery rate (CADR) for specific contaminants (usually dust, tobacco smoke, and pollen). The performance is a function of the inherent efficiency of the air-cleaning technologies used and the device airflow rate, as well as the indoor setting (see previous sections [Sections 2.1 to 2.4] for the factors influencing effectiveness of air cleaning process).

Presently, minimal data are available on the health consequences of using packaged air cleaners employing multiple technologies.

2.6 Ozone-Generating Air-Cleaning Devices

Certain air cleaners produce ozone by design to achieve air-cleaning effects and the removal of contaminants. Additionally, ozone can be produced as a by-product of air-cleaning processes. Any air-cleaning device that uses electricity during air cleaning process has the potential to generate ozone. In practice, ozone generation is associated with air cleaners that use high-voltage coronas or pin ionizers (e.g., some precipitators or ionizers), UV light of a sufficiently small wavelength (some photocatalytic oxidizers and UV-C air cleaners), and by some plasma air cleaners. Packaged air cleaners employing different air-cleaning technologies may use or produce ozone; examples include ozone generators or ionizers.

Ozone is harmful for health and exposure to ozone creates risk for a variety of symptoms and diseases associated with the respiratory tract (Koren et al. 1989; Touloumi et al. 1997; Bell et al. 2004). Many products of ozone homogeneous and heterogeneous reaction processes also create risks for health, including formaldehyde, unsaturated aldehydes (produced during the reaction of ozone with ketones and alcohols), and ultrafine particles (secondary organic aerosols) (Weschler 2006).

Ozone emission is thus undesirable. However, there is no consensus on the safe level of ozone. For example, ASHRAE's Environmental Health Committee (2011b) issued an emerging issue brief suggesting "safe ozone levels would be lower than 10 ppb" and that "the introduction of ozone to indoor spaces should be reduced to as low as reasonably achievable (ALARA) levels." Still, even widely used guidelines are not entirely consistent with all available epidemiological literature on the effects of ozone, and there is relatively little known about the long-term effects of exposure to low concentrations of ozone.

The current state of the science regarding the health effects of ozone strongly suggests that the use of air cleaners that emit ozone by design should not be permitted; the same information and advice is given by the U.S. EPA, among others (EPA 2013). There is more uncertainty about recommendations for air cleaners that do not use ozone by design for air cleaning but produce ozone unintentionally, as a by-product of their operation. There are devices that emit ozone but at the same time reduce concentrations of other harmful contaminants. The state of the science does not allow making highly certain trade-offs between increased exposure to ozone and the ozone reaction by-products and reduced exposure to other contaminants.

In the absence of robust information regarding safe levels of ozone, the precautionary principle should be used. Any ozone emission (beyond a trivial amount that any electrical device can emit) should be seen as a negative and use of an ozone-emitting air cleaner, even though the ozone is an unintentional by-product of operation, may represent a net negative impact on indoor air quality and thus should be used with caution. If possible, non-ozone-emitting alternatives should be used.

Attention must be paid to certain air-cleaning technologies that claim to produce radicals (e.g., hydroperoxy, peroxy, and hydroxyl radicals) that become airborne (gaseous state) as a means of effecting air cleaning/treatment. These species are ROS and are well known to be very short-lived in the gas-phase (airborne). Few studies in the peer-reviewed literature, if any, have measured these radicals in the gas phase as a means of an effective air treatment with such air-cleaning technologies.

2.7 Filtration and Air Cleaning Versus Ventilation

Filtration and air cleaning reduce exposures to selected air contaminants generated indoors, similar to outdoor air ventilation. Unlike ventilation, these methods can also reduce exposures to contaminants in outdoor air. The effectiveness of filtration and air cleaning is frequently expressed as the equivalent rate of outdoor air ventilation intake flow that would have to be provided to achieve the same effect. However, unlike outdoor air ventilation (essentially reducing concentrations and exposure to the majority of indoor-generated contaminants), filters and air cleaners (unless integrated) deal with one group of contaminants: either with particles, some types of gases, or microbial contaminants. The effectiveness is consequently the removal efficiency for a single contaminant, a class of contaminants, or a mixture of contaminants (Zhang et al. 2011).

To be expedient, the size of the effect obtained by filtration and air cleaning must be weighed against efficiency of other removal mechanisms (Nazaroff 2000) (i.e., outdoor air ventilation and removal by deposition to surface, see Section 2.1.1). For example, in the case of portable household electric room air cleaners, the product of single-pass efficiency and airflow due to air cleaning should be four times the sum of removal by ventilation and by deposition to meet the target of 80% continuous removal of particles (i.e., 20% or less of the initial particle load in a room, as defined by AHAM Air Cleaner Council [2013]). Furthermore, the cost and energy implications must be taken into account when comparing the effect obtained by filtration and air cleaning with outdoor air ventilation.

The Indoor Air Quality (IAQ) Procedure of ASHRAE Standard 62.1 (2013b) allows that filtration and air cleaning, together with recirculation, can be used as a substitute for a portion of outdoor air ventilation. This is conditional upon detailed analysis of contaminant sources, rates of contaminant removal by air-cleaning systems, contaminant concentration targets, and perceived acceptability targets (Burroughs 2006; Lamping and Stanley 2008; Grimsrud et al. 1999, 2011; Stanley et al. 2007; Dutton et al. 2013). There is, however, only limited scientific evidence showing that outdoor air ventilation intake flow can be partially or completely replaced by filtration and air cleaning.

One consideration that warrants discussion is that the overlap between contaminants with indoor sources versus those with external (outdoor) sources is relatively small and the use of increased ventilation air without filtration and air cleaning can result in substituting one set of contaminants (internally generated) with a different set (externally generated) with any associated health effects. This is especially important in regions that do not meet national or regional air quality standards for one or more criteria pollutants (i.e., ozone, PM10, PM2.5) or where there may be local sources of air pollution. In these instances outdoor ventilation air should be cleaned before being introduced into the building.

2.8 Maintenance, Commissioning, and Long-Term Performance of Filtration and Air-Cleaning Devices

At the design phase, filters and air cleaners are generally assumed to be installed and operating correctly. In actual installations, there could be air and contaminant bypass around air-cleaning devices (Ward and Siegel 2005), degradation in the performance of some technologies over time (Lehtimäki et al. 2002), and potential for the emission of primary and/or secondary by-products (Zhao et al. 2007; Rim et al. 2013).

Commissioning, active maintenance, and monitoring of filtration and air-cleaning devices are needed to ensure design performance. Additionally, filtration and air cleaners should be tested for extended durations to examine the possible change of performance in time of operation and the minimum period at which regular performance checks should be made. Information on these aspects is nearly nonexistent, and there are nearly no documents regulating and necessitating examination of long-term performance of filtration and air cleaning devices.

Indoor Air Quality Guide: Best Practices for Design, Construction, and Commissioning (ASHRAE 2009a), as well as NAFA's *Installation, Operation and Maintenance of Air Filtration Systems* (2012), provides guidance on maintenance and commissioning of filtration and air cleaning.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Summary Statements on Performance of Filtration and Air-Cleaning Devices

The following statements on filtration and air cleaning are proposed taking into account the evidence in the literature on their effects on health outcomes in public and residential buildings (excluding health-care facilities which were briefly summarized in the preceding chapters).The positions do not define minimum efficiency levels at which the effect of filtration and air cleaning can be regarded as providing health benefits, because the magnitude of the effects obtained by filtration and air-cleaning technologies depends on the design, operation, and setting in which these technologies are operated in a building. Also, in many cases there are no thresholds available for health effects, and regulatory exposure limits vary greatly among different cognizant authorities. Finally, the statements do not take any position on whether certain types of filtration and air-cleaning technologies should or should not be used in the built environment and under which conditions (except the position on ozone-generating devices and the long-term performance of filtration and air-cleaning devices); it was not the objective of the present document. It is regarded that the decision on this matter belongs to other committees setting out regulatory and guiding documents (codes, standards, and guidelines).

- Filtration technologies, in which particles are removed by attaching them to the media (often called *mechanical* or *media filters*), have been documented to be capable in many cases of reducing particle concentrations substantially, including reductions from levels being above to levels being below the associated regulatory exposure limits for reducing health risk set by recognized cognizant authorities. Modest empirical evidence suggests that mechanical filters will have positive effects on health, especially for reducing adverse allergy or asthma outcomes, but not on acute health symptoms in the general population, often called *sick-building syndrome (SBS) symptoms*. Models predict large reductions in morbidity and mortality associated with reduction of indoor exposures to particles from outdoor air, but these health benefits have not been verified empirically.
- Filtration technologies that generate electrical fields and/or ions, often called *electronic filters*, have been documented to range from relatively ineffective to very effective in reducing particles substantially, including reductions from levels being above to levels being below the associated regulatory exposure limits for reducing health risks set by recognized cognizant authorities. Within this broad characterization of air cleaners, ionizers have been evaluated to either show benefits or no benefits for acute health symptoms. Many electronic air cleaners emit significant ozone and are thus subject to special attention as advised by Position 1 in Section 3.2.
- There are sorbent air cleaners that have been documented to reduce concentrations of harmful gaseous contaminants substantially, including reductions from levels being above to levels being below the associated regulatory exposure limits for reducing health risks set by recognized cognizant authorities. There are very limited data on long-term effectiveness of these air cleaners for indoor air applications with mixtures of contaminants at low concentrations. Minimal empirical data exist on the health effects of using sorbent-based air-cleaning technologies.
- Air cleaners using photocatalytic oxidation (PCO) have been documented to remove harmful contaminants to levels being below the associated regulatory exposure limits for reducing health risks set by recognized cognizant authorities. However, there are PCO

technologies that are ineffective in reducing concentrations significantly, and there are PCO technologies that have also been shown to generate harmful contaminants during the air-cleaning process. No empirical data exist on the health effects of using PCO technologies. Different UV lamps used in many PCO devices can emit significant ozone and are thus subject to special attention as advised by Position 1 in Section 3.2.

- Short-wave ultraviolet (UV-C) energy has been documented to inactivate viruses, bacteria, and fungi. Some air-cleaning technologies using UV-C disinfection (also termed *ultraviolet germicidal irradiation* [UVGI]) have been documented, in a few studies, to show beneficial health effects when upper-room air, ventilation ducts, and evaporator coil surfaces were irradiated with UV-C. Some studies have failed to detect health benefits. Some UV lamps can emit significant ozone and are thus subject to special attention as advised by Position 1 in Section 3.2.
- Packaged air cleaners using multiple filtration and air-cleaning technologies are room air appliances intended for residential and small-space application. Their performance is subject to the advantages and disadvantages of the filtration and air-cleaning technology incorporated within the devices. Scientific documentation of the health effects of these devices on occupants is sparse and inconclusive. Some of the technologies incorporated into these devices either produce or rely on ozone for application and are thus subject to special attention as advised by Position 1 in Section 3.2.
- Filtration and air-cleaning technologies are often regarded as an attractive alternative to ventilation, enabling a reduction of outdoor air ventilation rate. The Indoor Air Quality (IAQ) Procedure of ASHRAE Standard 62.1 allows lower ventilation rates if alternative methods are used to reduce exposures to contaminants of concern, including the use of filtration or air cleaning. Limited data exist documenting the effectiveness of air cleaning, in particular gas-phase air cleaning, as an alternative to ventilation.

3.2 Positions on the Use of Filtration and Air-Cleaning Devices

ASHRAE holds the following positions on filtration and air-cleaning devices:

1. Devices that use the reactivity of ozone for the purpose of cleaning the air should not be used in occupied spaces because of negative health effects that arise from exposure to ozone and its reaction products. Extreme caution is warranted when using devices that emit a significant amount of ozone as by-product of their operation, rather than as a method of air cleaning. These devices pose a potential risk to health.
2. All filtration and air-cleaning technologies should be accompanied by data documenting their performance regarding removal of contaminants; these data should be based on established industry test standards. If not available, scientifically controlled third-party evaluation and documentation should be provided.

3.3 Recommendations on Future Developments of Filtration and Air-Cleaning Devices

Further development of filtration and air cleaning is needed, particularly in the following areas:

1. Quality control of operation of filtration and air-cleaning technologies, especially regarding data on their long-term performance.
2. Development of regulatory and guiding documents supporting design, operation, and maintenance of filtration and air cleaning devices.

3. Modification of methods of charging particles by electronic air cleaners to reduce the generation of ozone.
4. Integration of different filtration and air-cleaning technologies.
5. Development of air-cleaning technologies that support ventilation by removing air contaminants for which ventilation is less effective, such as proven and practical systems for removing ozone and possibly other gaseous pollutants from the air entering buildings.
6. Research on and application of intermittent use of filtration and air cleaners to deal with peak loads or unexpected releases of contaminants.
7. The extent to which air cleaning can enable reduction in outdoor air ventilation rates.

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List of ASHRAE Standards dealing with filtration and air cleaning:

- ASHRAE. 2008. ANSI/ASHRAE Standard 145.1-2008, *Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Loose Granular Media*. Atlanta: ASHRAE.
- ASHRAE. 2011. ANSI/ASHRAE Standard 145.2-2011, *Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Air-Cleaning Devices*. Atlanta: ASHRAE.
- ASHRAE. 2012. *ANSI/ASHRAE Standard 52.2-2012, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. Atlanta: ASHRAE.
- ASHRAE. 2013. ANSI/ASHRAE Standard 62.2-2013, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*. Atlanta: ASHRAE.
- ASHRAE. ND. ASHRAE Standard 185.1P, *Method of Testing UVC Lights for use in Air Handling Units or Air Ducts to Inactivate Airborne Microorganisms*. Atlanta: ASHRAE.
- ASHRAE. 2011. ANSI/ASHRAE/USGBC/IES Standard 189.1-2011, *Standard for the Design of High-Performance Green Buildings, Except Low-rise Residential Buildings*. Atlanta: ASHRAE.

List of ASHRAE Guidelines and User's Manuals dealing with filtration and air cleaning:

- ASHRAE. 2012. ASHRAE Guideline 26-2012, *Guideline for Field Testing of General Ventilation Filtration Devices and Systems for Removal Efficiency In-Situ by Particle Size and Resistance to Airflow*. Atlanta: ASHRAE.
- ASHRAE. 2010. *62.1 User's Manual*. Atlanta: ASHRAE.
- ASHRAE. 2009. ASHRAE Guideline 29, *Guideline for Risk Management of Public Health and Safety in Buildings*. Atlanta: ASHRAE.
- ASHRAE. 2009. *The Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning*. Atlanta: ASHRAE.

List of ASHRAE cognizant committees:

- TC 2.3, Gaseous Air Contaminants and Gas Contaminant Removal Equipment
- TC 2.4, Particulate Air Contaminants and Particulate Contaminant Removal Equipment
- SSPC 52.2, Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size
- SSPC 62.1, Ventilation for Acceptable Indoor Air Quality
- SPC 62.2, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings
- SPC 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings
- SSPC 145, Test Method for Assessing the Performance of Gas Phase Air Cleaning Equipment
- SPC 170, Ventilation of Health Care Facilities
- SPC 180, Standard Practice for Inspection and Maintenance of Commercial-Building HVAC Systems

Elevation and Acceptable Indoor Air Quality

1

Proposed Change

Proposal A

6.2.1.1.3 Air Density. Volumetric airflow rates are based on an ~~dry-~~air density of 0.075 lbda/ft³ (1.2 kgda/m³) (corresponding to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C))~~at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density, but such adjustments are not required for compliance with this standard.~~ Rates shall be adjusted for differences in air density due to lower atmospheric pressure at higher altitudes. Air density shall be adjusted for altitude by using higher elevation psychrometric charts or algorithms, or by using Equation 6-2a (I-P) or 6-2b (SI).

$$\rho = 0.075(1 - Z \times 6.8754 \times 10^{-6})^{5.2559} \qquad \text{(6-2a)}$$

$$\rho = 1.2(1 - Z \times 2.25577 \times 10^{-5})^{5.2559} \qquad \text{(6-2b)}$$

where
ρ = actual air density, lbda/ft³ (kgda/m³)
Z = site elevation, ft (m)

2

Proposed Change

Proposal B

~~**6.2.1.1.3 Air Density.** Volumetric airflow rates are based on dry-air density of 0.075 lbda/ft³ (1.2 kgda/m³) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.~~

6.2.4.4 Outdoor Air Intake. The design outdoor air intake flow (*Vot*) shall be determined in accordance with Equation 6-10.

Vot = Vou/Ev (6-10)

6.2.4.4.1 Air Density. Volumetric airflow rates are based on an air density of 0.075 lb/ft³ (1.2 kg/m³). *Vot* shall be adjusted for site elevation. Adjustment for design outdoor air conditions is permissible, but not required for compliance with this standard.

Informative Note: Methods for adjusting volumetric airflow rates for air density are available in engineering manuals, such as ASHRAE Fundamentals.

3

Proposed Change

Proposal C

~~**6.2.1.1.3 Air Density.** Volumetric airflow rates are based on dry-air density of 0.075 lbda/ft³ (1.2 kgda/m³) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.~~

6.2.4.4 Outdoor Air Intake. The design outdoor air intake flow (*Vot*) shall be determined in accordance with Equation 6-10.

Vot = Vou/Ev (6-10)

6.2.4.4.1 Air Density. Volumetric airflow rates are based on an air density of 0.075 lb/ft³ (1.2 kg/m³). *Vot* shall be adjusted for actual density at the outdoor air intake under cooling design conditions.

Informative Note: Methods for adjusting volumetric airflow rates for air density are available in engineering manuals, such as ASHRAE Fundamentals.

4

Proposed Change

Proposal D

~~**6.2.1.1.3 Air Density.** Volumetric airflow rates are based on dry-air density of 0.075 lbda/ft³ (1.2 kgda/m³) at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates shall be permitted to be adjusted for actual density.~~

6.2.4.4 Outdoor Air Intake. The design outdoor air intake flow (V_{ot}) shall be determined in accordance with Equation 6-10.

$$V_{ot} = V_{ou}/E_v \times E_\rho \qquad (6\text{-}10)$$

where
E_ρ = air density correction factor

6.2.4.4.1 Air Density Correction Factor. The air density correction factor (E_ρ) shall be determined in accordance with Table 6-5 or Normative Appendix D.

Elevation and Acceptable Indoor Air Quality 5

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Proposed Change

Table 6-5 Air Density Correction Factor

Outdoor Air Intake Elevation, ft	Outdoor Air Intake Elevation, m	E_ρ
< 515	< 158	1.00
515 – 1855	158 – 566	1.05
1855 – 3120	566 – 951	1.10
3120 – 4320	951 – 1317	1.15
4320 – 5460	1317 – 1664	1.20
5460 – 6540	1664 – 1994	1.25
6540 – 7575	1994 – 2309	1.30
7575 – 8560	2309 – 2609	1.35
8560 – 9505	2609 – 2897	1.40

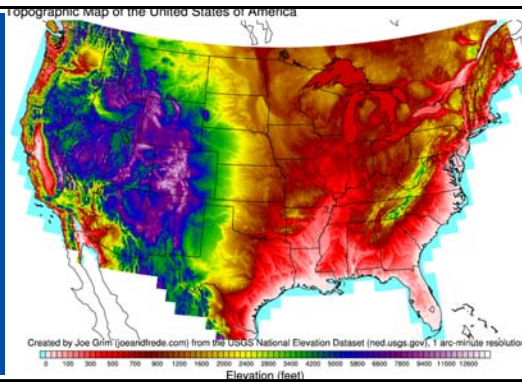
Impacts

Equipment Sizing
- Boilers
- Chillers
- Packaged

Energy Usage

Elevation and Acceptable Indoor Air Quality 6

6



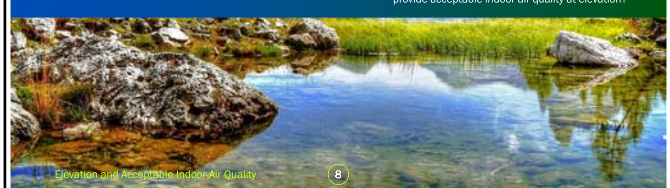
7

Basis of Decision

- Known impact of elevation on air density
- Fundamental basis of CFM minimum outdoor air requirements is mass balance equations

YET...

- 47 years of Standard 62 have not accounted for elevation impacts
- What collected data indicates current rates do not provide acceptable indoor air quality at elevation?



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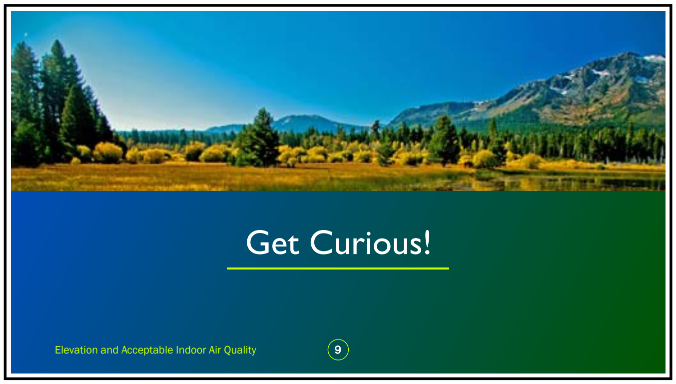
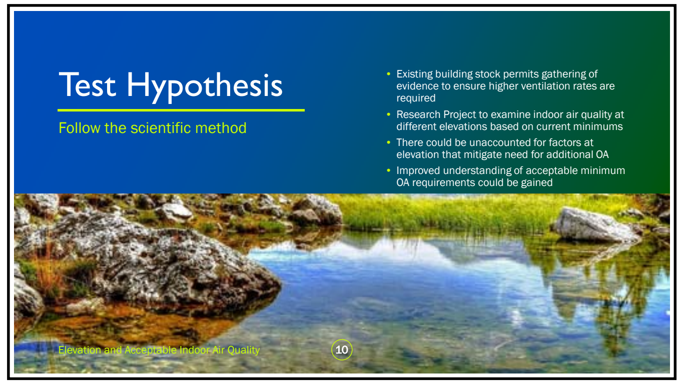

Get Curious!
Elevation and Acceptable Indoor Air Quality
9

9


Test Hypothesis
Follow the scientific method
• Existing building stock permits gathering of evidence to ensure higher ventilation rates are required
• Research Project to examine indoor air quality at different elevations based on current minimums
• There could be unaccounted for factors at elevation that mitigate need for additional OA
• Improved understanding of acceptable minimum OA requirements could be gained
Elevation and Acceptable Indoor Air Quality
10

10


THANK YOU!
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Email
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Elevation and Acceptable Indoor Air Quality

11

Why Density Corrections Should be Made

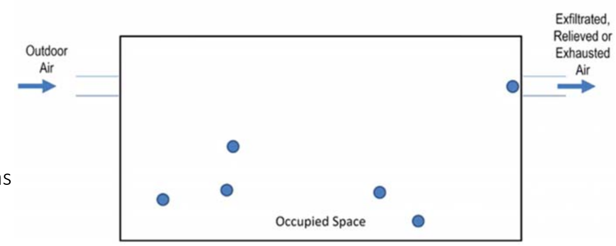
Ventilation rates are intended for dilution of the indoor environment.

- The rates are based on a mass balance air going in and air coming out of indoor spaces
- The published rates are listed as volumetric (actual) flows (cfm or acfm), standardized at specific density conditions 0.075 lbm/ft^3 at sea level 1 atm (14.69 psia), 70°F, 0% RH

The amount of mass by weight that is in a set volumetric flow rate of air, changes with the air density, which changes with pressure, temperature, and moisture.

Dilution with outdoor air is important for satisfaction of odor control and dilution of expect zone type off-gassing from both people and building components.

Corrected rates for dilution of unusual sources such as SARS-CoV-2, highlights additional importance.



1

The Impact of Density in Design

Elevation Atmospheric Pressure

Altitude (ft)	Pressure (psia)	Airflow (acfm)	World City	State / Country	Population (000,000)
Sea Level	14.696	100			
750	14.302	97	Charlotte	NC	872
1500	13.917	95	Munich	DE	1,475
2250	13.540	92	Edmonton	AB	981
3000	13.171	90	Billings	MT	110
3750	12.811	87	El Paso	TX	683
4500	12.458	85	Reno	NV	249
5250	12.114	82	Denver	CO	716
6000	11.777	80	Colo Sprgs	CO	465
6750	11.448	78	Loja	EC	180
7350	11.190	76	Mexico City	MX	8,851
8250	10.812	74	Addis Ababa	ET	4,793
8500	10.709	73	Bogota	CO	8,080
9350	10.364	71	Quinto	EC	2,239
10000	10.107	69	Huancayo	PE	425
11250	9.626	66	Cusco	PE	358
12000	9.346	64	La Paz	BO	845
13600	8.772	60	El Alto	BO	1,185

Cooling / Heating Design

Temp (°F)	Airflow (acfm)	World City
-30	123	Edmonton
-20	120	Quebec
-10	118	Billings
0	115	Denver
10	113	Reno
20	110	Charlotte
30	108	Cusco
40	106	Bogota
50	104	Huancayo
60	102	El Alto
70	100	Quinto
80	98	Addis Ababa
90	96	Colo Sprgs
100	95	El Paso
110	93	Phoenix
120	91	Mecca

Replacing Density with Airflow

Moisture Design

RH (%)	Airflow (acfm)
0	100.0
10	99.9
20	99.8
30	99.7
40	99.6
50	99.5
60	99.4
70	99.4
80	99.3
90	99.2
100	99.1

24% Under Min Ventilation

26% Under Min Ventilation

15% Above Min Ventilation

10% Under Min Ventilation

2

Real World Example

VENTILATION PROCEDURE - SYSTEM INFORMATION																	
System	Type	Ventilation Procedure	Total Area	Sum of People in Zones	Total People in System	Occupant Diversity	Design CFM	Minimum CFM	Uncorrected OSA, Vou	Uncorrected OSA, %	Average Outdoor Air Fraction, Xs	Maximum Zone OA, Zp	System Ventilation Efficiency, Ev	Corrected OSA, %	Corrected OSA, Vot	Provided OSA	Pass
RTU-1	Multizone Variable Air Volume	ASHRAE 62.1 - 2016	5,008	101	82	0.81	6420	1964	999	51%	0.58	-	0.58	27%	**1719**	**1725**	**YES**
RTU-2	Multizone Variable Air Volume	ASHRAE 62.1 - 2016	5,071	111	111	1.00	6030	2413	1631	68%	0.68	-	0.68	40%	**2413**	**2425**	**YES**
RTU-3	Multizone Variable Air Volume	ASHRAE 62.1 - 2016	7,078	184	184	1.00	8280	3394	2516	74%	0.74	-	0.74	41%	**3394**	**3400**	**YES**
RTU-4	Multizone Variable Air Volume	ASHRAE 62.1 - 2016	5,561	154	154	1.00	6960	2849	2071	73%	0.73	-	0.73	41%	**2849**	**2850**	**YES**
RTU-5	Multizone Variable Air Volume	ASHRAE 62.1 - 2016	6,619	84	84	1.00	12695	3204	1845	58%	0.58	-	0.58	25%	**3204**	**3225**	**YES**

VENTILATION PROCEDURE - SPACE INFORMATION																	
System	Zone	Room #	Room Name	Space Type	Area (Sq. Ft.)	Supply CFM	Distribution Configuration	No. of People	CFM/ Person	CFM/ Sq. Ft.	OSA CFM	Distribution Effectiveness	Corrected OSA	Minimum Required Supply CFM	Actual Mnimum Supply CFM	Evz (Zp)
RTU-1	ZONE 1-1	E20	KINDERGARTEN	CLASSROOMS (5-8)	971	1000	CSCRH	25	10	0.12	367	0.8	458	458	458	0.58
RTU-1	ZONE 1-2	E04	CORRIDOR	CORRIDORS	140	280	CSCRH	0	0	0.06	8	0.8	11	56	56	1.39
RTU-1	ZONE 1-2	E05	BOYS (3F)	-	121	245	CSCRH	0	0	0	0	0.8	0	49	49	1.58
RTU-1	ZONE 1-2	E06	STORAGE	-	76	0	CSCRH	0	0	0	0	0.8	0	0	0	1.00
RTU-1	ZONE 1-2	E07	GIRLS (2F)	-	110	255	CSCRH	0	0	0	0	0.8	0	51	51	1.58
RTU-1	ZONE 1-3	E02	CORRIDOR	CORRIDORS	242	300	CSCRH	0	0	0.06	15	0.8	18	60	60	1.28
RTU-1	ZONE 1-3	E15	KINDERGARTEN OFFICE	OFFICE SPACE	303	500	CSCRH	2	5	0.06	28	0.8	35	100	100	1.23
RTU-1	ZONE 1-4	E10	KINDERGARTEN	CLASSROOMS (5-8)	978	1240	CSCRH	25	10	0.12	367	0.8	459	459	459	0.58
RTU-1	ZONE 1-5	A06	LOUNGE	CONFERENCE/MEETING	270	350	CSCRH	14	5	0.06	86	0.8	108	108	108	0.58
RTU-1	ZONE 1-5	W01	CORRIDOR	CORRIDORS	180	250	CSCRH	0	0	0.06	11	0.8	14	50	77*	1.41
RTU-1	ZONE 1-6	A01	OFFICE	RECEPTION AREAS	338	350	CSCRH	11	5	0.06	75	0.8	94	94	94	0.58

COS District 11 BRISTOL ELEMENTARY HVAC

~~890 N. WALNUT STREET~~
COLORADO SPRINGS,
CO 80905

2020.09.21
Date

GENERAL NOTES FOR TABLE 6.2.2.1

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

3

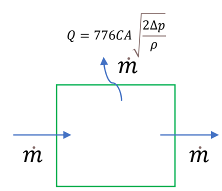
It Isn't a One Sided Equation

Getting the correct ventilation rate into the building is step 1

Proper dilution, requires getting the right mass of air to the zone as needed

Proper dilution requires also exhausting air out of the zone and building

A healthy building must maintain flow paths and pressurization.
- Pressure is created by the difference of airflow into and out of a zone
  - Ventilation component is essential to pressurization
- If density is not considered leaving the zone, it may lead to:
  - Imbalanced system flows and tracking
    - may affect energy recovery effectiveness
    - may affect Exhaust Air Transfer Ratio
  - Unintended infiltration
  - Unintended transfer air paths
  - Pressurization control of other zones



$$Q = SA - (RA + EA)$$

$$R = \frac{SA}{SA - Q}$$

$Q =$ *Pressurization Flow*
$R =$ *Space Pressurization Ratio*

4

Beyond Design Specification

ASHRAE Standard 111-2008 RA2017 states "certification that airflow rates meet specification is the most difficult field measurement that a TAB engineer has to perform" with outdoor air intakes being the worst.

- Our industry allows +/-10% tolerance for TAB.
- This leads potential is to be up to an additional unventilated 10%

ASHRAE Standard 62.1-2016 Addendum q Recognizes the challenges of measuring and maintaining ventilation airflow. Added these requirements:

- "allow field verification of outdoor air intake flow (V*ot*) during operation"
- "ventilation air distribution system for VAV and multispeed CV applications shall be provided with means to adjust the system to achieve at least the minimum ventilation airflow as required by Section 6 under any load condition or dynamic reset condition."
- "Systems with fans supplying variable primary air (V*ps*) shall be provided with any combination of control equipment, methods, or devices to maintain no less than the outdoor air intake flow (V*ot*)"

Key Takeaway: Ensuring correct ventilation is not only a design requirement, but a setup and operational requirement that not only requires correct calculations, but ongoing verification and controls.

5

Final Thoughts

Reminder: 62.1 ventilation rates are minimum requirements to achieve 80% satisfaction when there are no unusual contaminants of concern.

- It is typical due to energy trade off that these are the rates designed to and specified
- Achieving these satisfactory rates requires more than specification

Effective dilution requires a mass flow of air which needs to be designed, specified, and maintained in operation

- For a healthy building this requires attention to not only ventilation rates but supply, return, exhaust and exhaust rates
- Correction factors can be implemented in design, but also need to carry through TAB measurement or the volumetric rates can be subjected to same density errors

Alternative to correction factors is to use Standard airflow rates (e.g scfm) in 62.1 ensuring a mass flow requirement

- Design professionals currently use scfm in load calculation, and when selecting heat transfer and air moving equipment
- Reduces errors associated with design and TAB correction

6