Bill Bahnfleth, Ph.D., P.E., Presidential Member/Fellow ASHRAE

Wade Conlan, P.E., Member ASHRAE

Jason DeGraw, Ph.D., Member ASHRAE

Lew Harriman, Fellow/Life Member ASHRAE

Luke Leung, P.E., Fellow ASHRAE

Lessons Learned (So Far) From the COVID-19 Pandemic

The HVAC&R industry has been focusing on mitigating risk from the COVID–19 pandemic for almost two years. Between March 2020 when the ASHRAE Epidemic Task Force (ETF) was formed and now, the task force's members and the industry as a whole have learned a great deal.

In this roundtable, the chair of the Epidemic Task Force, Bill Bahnfleth, Ph.D., P.E., Presidential Member/Fellow ASHRAE, and other members of the task force—Wade Conlan, P.E., Member ASHRAE, lead of the ETF's resource inventory and building readiness team; Jason DeGraw, Ph.D., Member ASHRAE, the ETF's transportation team lead; Lew Harriman, Fellow/Life Member ASHRAE, a member of the ETF's residential team; Luke Leung, P.E., Fellow ASHRAE, the lead of the ETF's commercial/retail team; and Corey Metzger, P.E., Member ASHRAE, the lead of the ETF's schools team—discuss the lessons they have learned so far and brainstorm ways the industry can continue to move forward.

Bill Bahnfleth (ETF Chair): What are the top three lessons in priority order that your group within ASHRAE's Epidemic Task Force learned?

Lew Harriman (Residential): The first and most important lesson we learned pretty early—along with everybody else—is that it [SARS-CoV-2] is airborne. Because it's airborne, for risk protection we have to focus on reducing the concentration of viral particles, and also on reducing the duration of exposure. The next thing we learned from watching emerging literature

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Corey Metzger, P.E., Member ASHRAE

is that the big risks are indoors, and especially at home because of the frequency and duration of the exposure, i.e., eating meals and sleeping every day. Based on what we've seen from the studies, long daily residential exposure is a big risk because of the potential transmission between family members.

We needed to recommend interventions that would make economic and practical sense and that could be implemented quickly. For reducing time of exposure, you can't do much because you're going to be there at least in the morning, evening and all night long: sleeping, eating, taking care of children and simply living.

So if you can't reduce duration, then reducing airborne viral concentration will be the quickest and most effective short-term risk reduction measure. For that, opening windows in the home to dilute and remove the viral cloud is possible in some locations that have moderate climates. But it is not particularly effective and is often out of the question in most of the world because of weather, outdoor pollution or wildfires or because older windows sometimes simply won't open. So eventually we decided that in most cases, portable high efficiency particulate air filters (HEPAs) are probably the most immediate and lowest-cost means of reliably reducing concentration of airborne viruses in a home.

Luke Leung (Commercial): The first thing we learned quickly is the upgrade of the filtration devices is important because a lot of the commercial buildings are still hermetically sealed and have MERV 8 filters, especially in the U.S. We are seeing that change—maybe more permanently—regarding both the discussion of openings to outdoors and MERV 13 filters.

The second piece is we quickly saw the importance of flexible density in office buildings, and I think many of us will experience this kind of flexible workplace in the future where the density will be like an accordion depending on the risk of going to the office.

Third, we quickly learned a lot of the outbreaks are not inside the office boundary, including the elevator. A lot of people are concerned about a confined environment of the elevator, but we learned that the air change in new elevators can be beyond 300 cfm. And you do the math, it's well beyond 70 air changes per hour, a lot more than the typical office.

Corey Metzger (Schools): The key thing we learned is the number of school facilities that don't have ventilation systems at all or are significantly underventilated. Probably the most common question we received was how to handle the number of facilities that didn't have any ventilation or had only operable windows—what to do in those spaces.

Certainly we need to look at how to help continue to push the industry forward in addressing those needs in schools. I think the biggest areas of need seem to be in urban districts and rural districts.

From my perspective, the biggest question in the spaces that otherwise meet our recommendations is how to best distribute airflow. We've got a higher occupant density in a typical classroom than you're going to have in an office space or in many other occupancy types. Thinking about how we move air through the space to minimize the potential for transmission in the ETF's Core Recommendations, we're seeking a well-mixed space but looking at—as we move forward in the future—if there's a way to do it better to prevent transmission and understanding what that is.

The last item I would highlight are the steps we took for in-between spaces that either didn't meet our minimum recommendations or where there were more significant concerns—how we identify short-term improvements like in-room air cleaners and evaluate those and then get them implemented correctly, described in the air-cleaner document ["In-Room Air Cleaner Guidance for Reducing COVID-19 in Air in Your Space/Room"]. There's certainly potential to put those in as more or less a placebo. In many cases, it may not actually have much real benefit other than improving folks' comfort.

Jason DeGraw (Transportation): I think we as a team determined relatively quickly that any effective reduction in risk is only going to be accomplished holistically in as varied a situation as transportation. Not only are buildings involved—airports, bus stations, subway stations, that sort of thing—there are also the actual vehicles themselves. You're not going to be able to have an effective mitigation strategy or reduced risk for people if you're not attacking the whole problem. The weakest link is what's going to get you.

I think we felt there was definitely a bit of a communication problem. I think there were a lot of people in the general public that were much more worried than they should have been about some situations. Airplanes, for example, do a relatively good job of isolating the passengers to the extent that you can when you're on an airplane. But they're already doing the things that needed to be done in this case. On an airplane, you're not necessarily at that much risk unless you're sitting right next to an infected person.

The thing that I definitely learned is there are some forms of transportation that were just woefully unprepared or ill-equipped to respond to the pandemic. There have been some famous cases there that are a little bit shocking how the HVAC systems in those buses have been allowed to deteriorate. The same goes to a certain extent perhaps for trains and shipboard-type transportation as well. I felt comfortable flying based upon what I learned from the transportation team. I did actually fly a few times during the pandemic and didn't feel too much at risk.

So that was one of my really big takeaways—that we have a lot of work to do to protect people better from these sort of respiratory infections.

Wade Conlan (Building Readiness): It became apparent to a lot of individuals when we saw the lack of understanding of the equipment and systems that people actually had within their facilities—let alone even having them understand how well they were operating—or how poorly they were operating—and whether they actually provided outdoor air. I think that was a big eye opener for a lot of other people.

Another one was trying to understand and get people to shift how they would evaluate something for an implementation. More times than not, people are making decisions based strictly on energy. Having them understand the balance between indoor air quality (IAQ) and energy when you're doing this—really looking at cost versus risk reduction versus energy versus availability of the different measures—was a balance that needed to be created for people. Because of the multitude of systems out there, there were just infinite options.

The last one was how to determine what we tagged as equivalent, outdoor air or clean air in the Wells-Riley equation, how to evaluate your system for how much quantity you have as well as looking at the systems as they're operating to see how much you're actually delivering to the space. It was done for flushing for the building readiness, but I think it really lends itself also to when the space is occupied.

Bahnfleth: From my perspective, the first thing I'd note is that we found buildings of all types are not really COVID-ready. There weren't many cheap, quick options for getting buildings to where we want them to be, which is something of an indictment of our approach to minimum standards that we might want to deal with in the future in case something like this happens again—which it will, eventually.

Another thing that has struck me is the low level of understanding of indoor air quality, not just amongst the public, but amongst professionals too. That's a consequence of how we educate the people who design, construct and operate buildings. That's been a significant impediment to a timely and effective response.

The third lesson I've learned is that, strangely, no matter how bad things are, there is reluctance to do anything to upgrade buildings that involves significant investment. We're almost two years into the pandemic, and many who are still trying to figure out what they're going to do, or if they're going to do anything. I get the feeling that many owners have been hoping it's going to end soon. And then when it doesn't end soon, they hope it's going to end pretty soon. It seems there is a widely-held feeling that we can just go back to normal afterward. That has big implications for whether we're actually going to be able to change things in the future, and it's something to keep in mind. We shouldn't assume that everyone's going to say, "Oh, yes, let's change all of our standards and really upgrade the way that we design buildings for resilience and for indoor air quality."

Bahnfleth: What are the implications of these lessons learned for changes to standards and guidance?

Conlan: I think the biggest things that you're going to see is an adjustment to outdoor air. And since Standard 62 in code is really for acceptable indoor air quality, are we going to try and push something that would be beyond that? I also think that code wise—and we've seen it in California—is the filtration levels for just typical buildings and the potential for those to be increased.

Bahnfleth: From what you've learned, what should change? Not "Will it?" but "Should it?"

Conlan: I'll go back to the fact that people didn't understand how their buildings worked. I think what should change is that owners should actually have a

systems manual that describes what equipment they have and how does it work, so they can understand how to adjust it for a different pandemic or a different type of item.

I'll come back to what should change—just how outdoor air is treated within documents and designs. Having a much better documented way for building pressurization, for indoor air quality (IAQ) control, for minimum pressurization, for all the different modes and making sure those systems can control to that. There are a lot of systems that get designed that are just expected to be set by testing, adjusting and balancing (TAB) and be done. That's not realistic moving forward.

DeGraw: Mainly, I agree with what Wade was saying. The owners and operators need to better understand how their buildings work. I feel like there is hope on that front because it really dovetails with the energy benchmarking requirements that have started to appear throughout the country. That is requiring owners and operators to better understand how their buildings work, and maybe it is up to us to make sure we take advantage of that opportunity and maybe expand some of the scope of that. It's not just a box-checking exercise in terms of getting the right form into the city or whoever's requiring the information, but actually going a little deeper and making sure they understand what their building is doing and not falling prey to "my building is better than average" syndrome.

Harriman: I'd like to propose a modest solution to this problem of building owners not really understanding their systems. I think we need an enforcement mechanism that works over time, and I really think that's going to be public attention. Maybe the best way to do that, as part of ASHRAE standards, would be to decide what are the appropriate real-time metrics for infection control. Those measurements need to be visible to all, on the wall next to the thermostat. Temperature control has that public-visibility enforcement mechanism. Similarly, if the occupants could easily see the numbers that show the building is not being well ventilated and that indoor air is not being adequately filtered in real-time in each room, I imagine shortcomings would not persist over months and years.

Real-time measurements—visible to the occupants—would become a gentle and constant encouragement to the building owner to invest the money that it takes to understand the building, and to do something to improve air quality when relevant risk metrics show action is called for.

Otherwise, I think that without providing a mechanism for measuring and displaying relevant risks in real time for occupants, ASHRAE's saying that "everyone should understand their buildings" is not going to make much of a difference.

Bahnfleth: I agree. Disclosure programs would be a good thing if they were done in such a way that the information was actually reliable and motivational. We do it for energy, why not for indoor environmental quality?

Harriman: Defining adequate indoor environmental quality metrics is always tricky from an ASHRAE perspective. Within ASHRAE we will need to finally decide that a range from x to y parts per million CO_2 represent thresholds of increasing concern (as a proxy for probable increase in human-generated airborne infectious particles). Then after ASHRAE agreement on thresholds of concern for airborne infection, setting those ranges into standards also requires careful thought. We don't want to burden all buildings with excess ventilation and filtration during times when airborne infection is a low risk—or no risk at all.

But in any case, I think that without relevant measurements that show that building owners are "getting what they're paying for" in terms of air quality and infection risk reduction, the usual randomness in ventilation and filtration will probably continue. Air quality is just too tough for most people to measure and perceive with their own senses.

Bahnfleth: Corey, anything to add here?

Metzger: The thing that I would like to see is our codes and our standards having some means for demonstrating air-distribution effectiveness throughout the entire operating range for systems. We've talked several times about variable volume systems and the potential for air-distribution effectiveness to decrease as we decrease airflow into a space, which could also be an issue with some demand-controlled ventilation systems.

Making sure our systems provide good air distribution in a space throughout throughout their entire operating range is something I think our standards need to reinforce. I'm not saying that they may not state it today, but we may need to provide some additional metrics or prescriptive requirements that can help people understand when they're designing how to accomplish that. I think

there are many spaces that might be safe at full airflow or might be safe at full outdoor air. "Safe" may not be the right term, but much better at those conditions than they are during the heating season, for example, in Northern climate zones.

Bahnfleth: That's a great point. Should we change our design focus from having a certain amount of outdoor air or having air distribution that achieves a certain metric to limiting specific contaminant exposures in real time? It would be moving from a prescriptive approach to a performance approach—looking at the outcomes instead of the inputs.

Metzger: I think my biggest concern is that contaminants could be in one portion of a space and not another, or there's a source for the contaminant in every space. If our air distribution isn't effectively removing the contaminant from that portion of the space, and we've got a sensor on the other side of the space, what good does the sensor do? It's not to say that it doesn't do some good, but it may not meet our expected goal.

Bahnfleth: I was thinking more of diagnostic procedures than one where we put sensors. But I do think this is an issue that may come up later: more demand control is going to be critical to overcoming objections to the energy use impact of achieving higher levels of IAQ because if you implement them without sensing and modulation of the things that have energy costs then we're going to wind up getting beaten up for that.

Bahnfleth: Luke, what have you got on this topic?

Leung: Number one is broaden the bookend of design to include future events, such as future pandemics and wildfires. It could be a symbol of a pandemic mode or a wildfire mode in a building management system (BMS) to automate that process to a certain extent. The building will be a demand-based operation rather than a one-size-fits-all operation. If there's a wildfire, you go to wildfire mode and change the filter.

The second thing is we haven't been paying attention to microbials in offices, and I'm not talking about the COVID-19 pandemic. I'm talking about a simple flu that kills many people and reduces production of office work. What we are seeing now and is already in motion is there are sensors out there that can sense up to 1,000 different microbial types. They are not real-time, but it starts informing the trend of "is a flu virus ratcheting up in your office." There are office buildings that are thinking and incorporating the microbial dimension of monitoring.

Number three is beyond office buildings. The pandemic also revealed that some of our buildings are so poorly designed for our senior citizens, as in nursing homes. That has to change. We cannot afford for those people to die like that.

Bahnfleth: Maybe the question we should discuss is whether we're going to recommend and maybe make upgrades to standards to reduce risk. What is acceptable risk?

Harriman: I'd like to point out that ASHRAE as a Society is working hard and wrestling with one fundamental aspect of that question, which is how do we define a healthy environment? And before that, how do we define health and wellness? An ASHRAE multidisciplinary task group is currently wrestling with those questions (MTG:HWBE—Health and Wellness in the Built Environment). I've been told by members of the task group that progress has been difficult because the concept of wellness is complex, especially since ASHRAE has a worldwide perspective.

Conlan: I think ASHRAE actually has somewhere it's implied, and I looked at ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*, because its ventilation table isn't just a ventilation table. It actually deals with filtration and space pressurization. Now, does it include all the science behind it and tell you the risk reduction and the impact of those different items? No, I don't believe it does; however, it's at least going beyond just a document that deals with outdoor air, and it's one that indicates filtration level and pressurization. While it may need to be improved or expanded, they are inherently telling you that there are different risk levels that they're trying to mitigate for the different spaces, so they're assigning different requirements.

Bahnfleth: Something I find very interesting about Standard 170 is that of all of the ground facilities standards that ASHRAE has for indoor air quality, it's the one that doesn't have a definition of acceptable indoor air quality in it. It says that the goal includes asepsis, but it doesn't say to what extent. I can look at Standard 62.1 and see that it says, "No known contaminants at harmful concentrations and 80% of the occupants not dissatisfied." I may not like that definition, but at least I can understand it. So while it clearly prescribes ventilation

and filtration that are going to improve infection control, it doesn't really say what success is.

Conlan: And that's why I said it's implied, by the different values, but it doesn't tell you what level that's going to achieve within the space.

Harriman: I'd like to echo and agree with what Luke suggested earlier: maybe ASHRAE will need to think about modifying standards to make systems COVID-ready, so that they have a pandemic or wildfire mode. In other words make improvements to design and control of ventilation and filtration that allow effective response to periodic increases in indoor and outdoor health risks over the lifetime of the building.

Also, it seems to me that risk is a fluid metric because it varies so much according to time of occupancy and the type and number of occupants. I suspect we may not be able to settle on a single standard for acceptable risk that applies to all buildings. Acceptable risk standards will need to be different when the consequences of system shortcomings affect especially vulnerable occupants and/or larger or smaller numbers of occupants. Probably different risk standards apply for a nursing home versus a sports bar versus a transportation center versus a single family home in Manitoba or a high-rise apartment in Singapore.

Conlan: I just did a design review for a facility, and it was actually the first time I've seen pandemic modes for different parts and pieces. They actually had a control diagram for an air-handling unit and right next to it was the control diagram for pandemic mode for that unit. They actually had an entire sequence. Now, I haven't gone line-by-line to see if I agree with everything that they're doing, but it is nice to see a shift of people saying, "Hold on a second—we do need to do what Luke and Lew are saying." This is for actually for a health-care facility, but it was nice to see actual sequence and diagram on a drawing: pandemic mode for the air-handling unit versus normal mode.

Metzger: My only thought is I would like to see, and this probably starts at maybe the Environmental Health Committee: a proposed percentage level of risk reduction that could be used for standards and could be referenced in standards: we're going to try to reduce risk by 98% or by 90%. By something that's defined because then we can say how we are trying to do that, and then with that information documented, folks could look at our standards and say, "Okay, your target is 90%. We want to be at 99. We need to go beyond the defined baseline."

I think we're always going to have the arguments that came up, or the discussions that came up, about what is the right flow rate for non-infectious air delivery? Right. So I would like to see us draw a line and say, "This is the line that we've picked. It doesn't mean it's the right line for your facility, but at least gives you a marker to judge from."

Bahnfleth: I have a follow onto that. We had several problems there. One was what's our definition of acceptable risk? The next is, can we even calculate that risk with sufficient accuracy? It's very uncertain, I don't think it's ever going to be a lot more certain than it is now. Ten years from now, we may know what we should have done for COVID, but maybe not even then. And the other thing is that we're kind of getting a little bit blindered here by focusing too much on HVAC as the way to reduce risk. It is just one layer in an overall risk mitigation program. We need to determine how much is reasonable to do with HVAC and how much to depend on other controls.

For example, at some point, you've got to cut occupancy or you have to lock down or you have to do other things that are out of the realm of what ASHRAE does. More of an appreciation for the whole hierarchy of controls is something that's going to be important going forward so that we can maybe get agreement on things that are reasonable to change in our standards.

DeGraw: I have always preferred passive protections over active protections because things like a pandemic-mode—that's something we encountered in TC 2.10, Resilience and Security, talking about building security—people put in control sequences and then people retire, people move around, and nobody knows what it does anymore.

Bahnfleth: Well, there's certainly lots of history from the bioterrorism days that would support that.

DeGraw: I think this idea of risk reduction, or appetite for risk, is part of a broader question: what is our tolerance for lack of resilience in buildings? This is maybe just one sort of smaller aspect to that. I think it's easier to talk about things like sea level rise and other things for which there's this threshold of some event out in the future that we know may happen. But when you've got a pandemic that could happen tomorrow or that couldn't

happen again for… who knows? It's just harder to talk about that in terms of just acceptable levels of risk.

Harriman: People want engineering controls to make the building "safe," by which they generally mean they won't have to take precautions, or change the way they occupy a building. But there's no way that mechanical equipment and systems by themselves can ever reduce risks to zero. Based on conversations I have had with many senior managers dealing with buildings during this pandemic, they and the public often overlook this fact of life. Too often they hope and expect to have "safe" buildings by adding some low-cost, widely-available, easy to install and highly effective technology, without first reducing risks by reducing the viral load.

Reducing viral load means reducing occupancy, wearing masks indoors and reducing the number of viruses generated per person, which requires vaccination. Without these measures, HVAC improvements alone—no matter how costly or technically impressive—will not provide acceptable risk levels that we in ASHRAE—and the public—might ultimately agree on.

Bahnfleth: This comment about passive versus active raises an important question: passive measures are there all the time, and there are some who would like to see a rising tide raise all boats, and passive measures are going to affect air quality all the time. Should we be linking those together, making buildings better from the point of view of infection control and also addressing some of the other things we've known for a long time about air quality deficiencies in buildings and the consequences?

DeGraw: Absolutely, yes. You don't get these opportunities to make a real difference too often, and this is a real opportunity. Everybody is talking about indoor air quality right now. Everybody thinks they understand indoor air quality, so it's not just an opportunity educationally but really across the board. If we don't make the changes and make them stick, they're not going to be here in a couple years, just based on the lessons out of

the bioterrorism scares. Nobody really talks about that anymore.

Bahnfleth: To your cautionary tale, more than fifteen years ago when we were doing a lot of research on bioterrorism defense, I went to a meeting with a sponsor from a government agency. The gentleman I was speaking with said, "You know, if there are no more attacks in five years, all of this will go away." And it did, the investment went away, and the implementation went away and hardly anything changed. And that's my biggest worry.

Leung: To that point, I think we should think about the measures that can impact both the emergency times and also the normal times in order to make them stick a little better. Now, a couple things came into mind. For example, in China a new energy code is starting April 1 mandating all buildings consider operable windows because of energy and health reasons. Now I'm not saying that's right or wrong, but I'm just saying one of the potential ways of thinking.

The other trend the industry has been moving toward is this dynamic outdoor environment or half climate space, whatever you call it, semi-conditioned. What is our position on those measures and other measures that can impact energy, health and its impact on both our normal and emergency times? I think those will be more likely to stick around.

Conlan: I'm going to tie in some of the other questions. Something I've thought of is we all get questions about what should we do with our HVAC system. Whether from professional colleagues or from the general public, those lines really are blurred. I basically kept getting the same question of, "Have you seen this product, and should I use it?" What that really shows is how much HVAC&R became a focal point for the world during this pandemic.

It's time to make sure that we start doing it right moving forward. ■