virtual event

Protecting Transportation Workers and Passengers from COVID:

Gaps in Safety, Lessons Learned and Next Steps" – Testimony of William P. Bahnfleth, ASHRAE

Before the U.S. House of Representatives Committee on Transportation and Infrastructure: Hearing on "Protecting Transportation Workers and Passengers from COVID: Gaps in Safety, Lessons Learned and Next Steps" [1]

Editorial introduction.

This news item is included in the REHVA Journal to demonstrate how professional association may be able to play a role at policy level by sharing their information with responsible policy makers, like in this case the U.S. House of Representatives. I can imagine that our REHVA members may be in a similar position towards their national legislative authorities. This news item demonstrates how this can be done and how we may effectively make use of the information that is widely available via the IEQ-GA website (www.IEQ-GA.net) and at our REHVA website.

Jaap Hogeling, Editor in Chief REHVA Journal; Secretary/treasurer of IEQ-GA Board.

I am testifying today on behalf of ASHRAE, a professional and technical society made up of more than 55,000 individual members founded in 1894. The President of ASHRAE, Charles Gulledge, also wants to extend his thanks for your investigation of this important subject. He asked me to share his message: "Protecting the transportation workforce and passengers, many of whom are essential workers, is critical for all of us, as those traveling can rapidly spread the coronavirus over large distances. I am delighted that you have called upon the Chair of ASHRAE's Epidemic Task Force who is one of the leading experts in this field. On behalf of the entire ASHRAE organization, we offer continued technical support to your committee as you work on policies and legislation to make transportation systems safer and healthier."

In response to the pandemic, ASHRAE formed an Epidemic Task Force last March, which I was appointed to chair. The Task Force is comprised of volunteer members who are experts in the fields of air conditioning, ventilation, filtration and air cleaning. It includes practitioners as well as researchers and academics like myself who have focused their careers on making indoor environments safer and healthier. Importantly, as part of ASHRAE, the task force like all activities at ASHRAE, is free from commercial interests. Our guidance, standards, and other resources are based on science and consensus. The Task Force has produced hundreds of pages of guidance materials, conducted more than a hundred instructional webinars and courses, held briefings for policy makers, and developed summaries of this guidance that can be more accessible to the general public.

ASHRAE's Epidemic Task Force has produced a 43-page guidance document specific to transportation systems (see 2). This guidance is based on current understanding of how COVID-19 is transmitted and on the principles of infection controls applicable to indoor environments generally, which includes mobile environments such as cars, trains, buses, aircraft, and ships. I will begin by reviewing those foundational considerations and then relate them to the transportation applications.

According to the US Centers for Disease Control and Prevention (CDC) as well as other public health authorities such as the World Health Organization (WHO), COVID-19 transmission is believed to be possible through three modes:

- Short range "droplet" transmission that occurs when an infected person and a susceptible one are sufficiently close together that large virus-containing droplets emitted by the infector through activities such as breathing, speaking, talking, coughing, and sneezing land in the eyes, nose, or mouth of the susceptible person. This mode of transmission is addressed by social distancing and use of masks, which limits the distance that infectious droplets travel and also the quantity of droplets. It should be noted that while the customary guideline in use for distancing is six feet, it has been shown experimentally that a sneeze may project a cloud of infectious droplets more than 25 ft from the source in still air. Air currents in an indoor environment may carry these infectious clouds over even larger distances. There is strong evidence for droplet transmission.
- Intermediate surface or "fomite" transmission that occurs when an infected person contaminates a surface that is touched by a susceptible person who infects themselves by touching their eyes, nose, or mouth. Fomite transmission is controlled primarily by personal hygiene, i.e., not coughing or sneezing into one's hands, regular hand washing, and not touching the face, and by disinfection of surfaces, especially high touch surfaces like door handles. While still deemed possible, the perceived importance of fomite transmission has decreased over the course of the pandemic and there is little evidence that it is a significant mode of transmission.
- Airborne transmission resulting from the inhalation of infectious aerosols, the particles produced by drying of respiratory droplets that are sufficiently small to remain airborne for long periods of time and to become distributed throughout an indoor environment. Airborne transmission has been divided by some into short range and long range airborne transmission, as aerosols are always present even within the range associated with droplet transmission and may contribute significantly to risk within the 6 ft distancing radius.

Airborne transmission risk is controlled by "engineering controls" associated with heating, ventilating, and air-conditioning (HVAC) systems, including dilution with outdoor air, exhaust of contaminated air at its source, control of indoor air flows, filtration to remove infectious particles from the air, and air cleaners that capture or destroy infectious particles. Risk is also reduced through the use of masks, which reduce the amount of infectious material emitted into the air as well as the amount inhaled by a susceptible person. The focus of ASHRAE's COVID-19 guidance is mitigation of airborne infection risk, but within the context of a layered infection control strategy that addresses all significant modes of transmission.

Early in the pandemic, WHO, CDC, and other health authorities were highly skeptical of the significance – or even possibility – of airborne transmission. Based on evidence of airborne transmission at the time, ASHRAE and some other organizations concluded that while definitive proof might not yet be available, there was sufficient reason to suspect airborne transmission that it should develop guidance to prevent it. Over time, the potential for airborne transmission became clearer and, since October of last year, however, both WHO and CDC have recognized that it can occur under certain circumstances and now recommend taking precautions against it. An important characteristic of airborne transmission is that it is proportional to airborne concentration of infectious particles, duration of exposure of susceptible persons, and the type of activities taking place. For example, an infected person exercising in a fitness center will shed infectious droplets at a higher rate than a sedentary individual and susceptible exercisers will inhale droplets at a faster rate.

These modes of infection may occur in any type of indoor environment, but the extent of the risk represented by each mode and the extent to which it can be mitigated varies with the characteristics of a particular environment.

ASHRAE's COVID-19 guidance currently addresses nine different facility types: residential, multifamily, healthcare, residential healthcare, commercial, communities of faith, school and university, laboratory, and transportation. Additional guidance is under development. The recommendations for each of these indoor environment types involve applications of the same engineering controls in ways appropriate to the specific indoor environment.

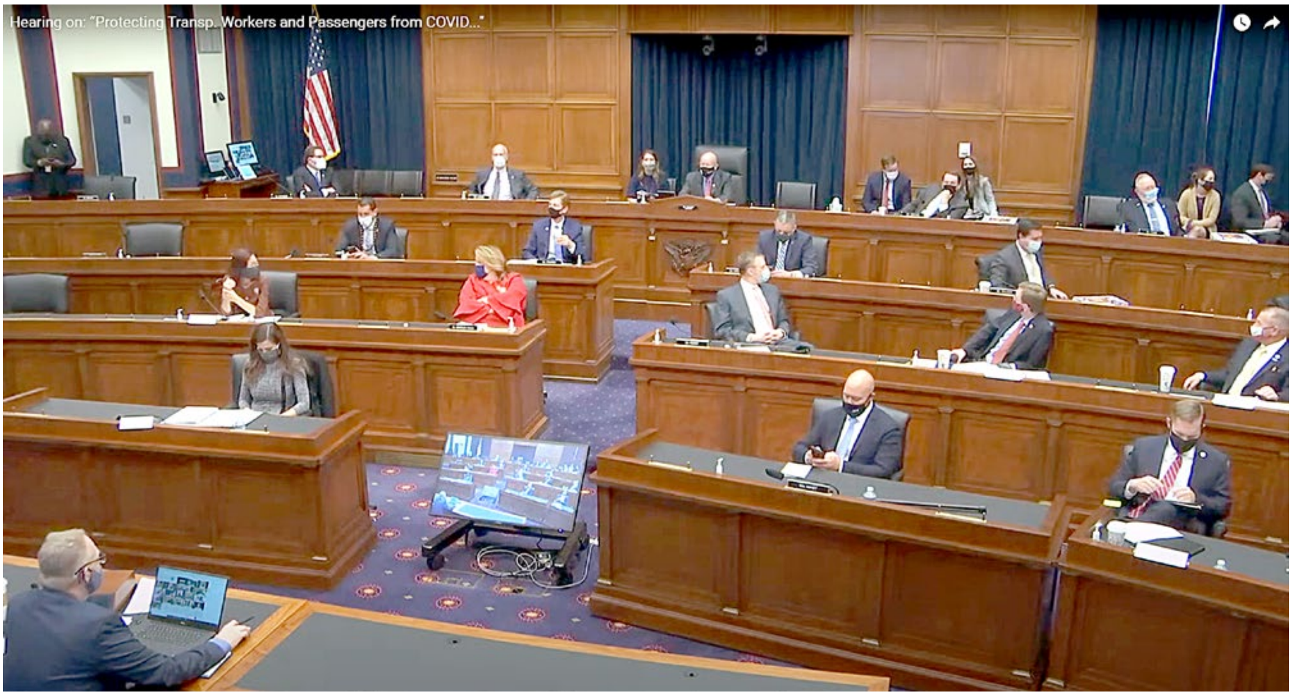
- Ventilation with outdoor air. Outdoor air is normally free of indoor pathogens, particularly viruses, which do not survive well outside the body. Outdoor air is mixed with indoor air, diluting viral aerosol it may contain and replacing potentially contaminated air that is exhausted at an equal rate. Ventilation is the most fundamental control for control of all contaminants. For buildings, a minimum amount of ventilation based on the type of use, number of occupants, and floor area is generally required by codes that are based on ASHRAE Standard 62.1 for non-residential buildings, Standard 62.2 for residential buildings, and Standard 170 for healthcare facilities. For non-healthcare facilities, the minimum ventilation requirement specified in the standard is not sufficient to provide a high degree of protection from airborne transmission.
- Air distribution. Air movement in indoor spaces can have positive and negative impacts on infection risk. Poor circulation of air in a space can result in poor removal of contaminants by ventilation. High velocity currents of air created by HVAC systems can create risk of extended droplet transmission. However, directional airflow can also be used to efficiently remove contaminants when the location of the source is known, for example, when an infected patient is in bed in a hospital patient room.
- Filtration. The filters used to remove particles from indoor air are typically composed of densely matted fibers. A range of filter efficiencies are available. The MERV rating system established by ASHRAE Standard 52.2-2017 is most commonly used for filters found in HVAC systems. MERV ratings range from 1 – 16 with higher numbers representing filters that are more efficient, particularly for small particles in the size range associated with respiratory aerosols. Current minimum filter efficiency requirements in ASHRAE Standards 62.1 and 62.2 are MERV 8 and MERV 6, neither of which removes fine particles with high efficiency. As in the case of minimum ventilation rates, minimum filtration requirements do not provide much protection against airborne transmission.
- Air cleaners. A large number of technologies are available that disinfect air via different process. This includes many for which the evidence for efficacy and safety is lacking. If effective, air cleaners can be adjuncts to ventilation and filtration. The best-established technology currently is disinfection with germicidal ultraviolet light, which can be applied in a number of different ways, both inside occupied spaces and in HVAC systems.

ASHRAE's Core Recommendations for Reducing Airborne Infectious Aerosol Exposure 3 summarize guidance for HVAC system design and operation changes to reduce risk of COVID-19 transmission. The recommendations address the following key points:

- *Public health guidance should be followed.* Social distancing and good hygiene help reduce droplet and fomite risk and indoor mask use in public spaces during the pandemic reduces both short and long-distance exposure.

- *Minimum levels of ventilation and filtration should be maintained and may be exceeded if necessary, to achieve desired levels of exposure reduction*. Code minimum ventilation and MERV 13 or better filter efficiency should be viewed as baseline requirements that may not be sufficient. A requirement to increase outdoor air is not needed if exposure can be reduced sufficiently by other controls.
- *Air cleaners may be used as a supplement to minimum ventilation and filtration to achieve risk targets*. Only those demonstrated to be safe and effective should be used.
- *Ventilation, filtration, and air cleaners may be combined to achieve exposure reduction goals while minimizing energy use*. The energy cost of increased outdoor air flow, which must be brought to the indoor temperature, can be significant and a disincentive to increase protection. Filters and air cleaners can also reduce the amount of active virus in the air and may be able to do it with lower energy use and operating cost.
- Unless a directional airflow strategy is applicable, *air distribution should not create strong air currents in the occupied part of a space that can blow large droplets from person to person and should thoroughly mix the air in a space*. As noted previously the range of droplet transmission can be extended by high velocity air flows. Some studies of ventilation in healthcare facilities have found that in many cases good mixing of room air results in lower exposure than stratified air distribution.
- *Ventilation systems should operate whenever occupants are present and outdoor air flow should not be reduced from its design values*. Systems should remain in operation when, for example, janitorial or maintenance crews are present. Demand controlled ventilation, which reduces outdoor air flow in proportion to the number of people in a space, should not be used because it slows the removal of infectious particles and increases their concentration in the air.
- *Re-entry of potentially contaminated air should be limited to safe values*. Infections may be transmitted by recirculation of exhaust air in in some types of energy recovery devices, placement of exhausts too close to outdoor air intakes, and by unintentional air flows through plumbing and ventilation shafts. Unintentional airflows were identified as the cause of outbreaks during the SARS epidemic. Recent investigations indicate that COVID-19 can be transmitted in this way.
- *Systems should be commissioned to verify that they are functioning as designed*. Many existing HVAC systems are not properly maintained and, as a result, use more energy than necessary and may not provide good control of indoor air quality.

Further, in assessing risk related to transportation, an end-to-end approach should be taken that includes the entire trip, not only, for example, time spent on an airplane. An air traveller may take a train to the airport, then spend time in the terminal prior to boarding and, after arrival must again move through the terminal and may again use public transportation to reach their destination. Any of these steps in the process may be the cause of transmission.



Ground facilities associated with transportation, including terminals, stations, hangars, garages, barns, and business offices have much in common with facility types for which extensive guidance is already available from ASHRAE and others. It should be possible to apply effective airborne protections to such facilities. A primary concern for public facilities such as terminals is the combination of large transient populations passing through them and the difficulty of maintaining distancing and of keeping the many high touch surfaces disinfected.

Although they are not stationary, aircraft, ships, cars, buses, and trains are, nevertheless, indoor environments typically provided with some level of HVAC system. Therefore, the same engineering controls applied to buildings potentially can be applied to them. However, they are by no means simply small moving buildings. Aircraft, ships, cars, buses, and trains are all relatively small enclosed volumes in which the density of people is ordinarily much higher than in buildings. This density inherently increases the risk of short-range transmission and it is difficult, if not impossible, to isolate passengers and workers in some cases, for example, in taxis. Ships, particularly cruise ships, bear more resemblance to land facilities but still provide many opportunities for close contact and fomite transmission.

Transportation HVAC systems vary greatly in terms of the levels of ventilation and filtration they provide. Aircraft HVAC utilizes high recirculation rates through very efficient (HEPA) filters to greatly reduce airborne transmission risk, and aircraft maintenance is typically very thorough. There is a much wider range of conditions in trains and buses. Ventilation rates are likely to be low, and filter efficiencies not sufficient to provide good control of infectious aerosols. Ability to provide protected environments for workers that are isolated from the passenger environment also vary. Bus and taxi drivers, in particular, are exposed to the same environment as passengers in an enclosed environment that may not be well ventilated. HVAC systems on ships may be more like those in buildings with respect to ventilation and filtration, but the layout of ships can make distancing difficult. These differences affect the requirements for, and even the feasibility of making substantial reductions in risk. In some cases, control options are limited by security concerns, for example the risk of fire from malfunctioning electronic air cleaning devices in buses.

Numerous case studies have been published investigating the transmission of COVID-19 during the current pandemic, mostly focused on aircraft, cruise ships, and buses. Similar studies in the past have investigated transmission of SARS and other diseases, particularly influenza. A few examples will serve to illustrate typical findings. Even in the highly ventilated, HEPA filtered environment of aircraft, transmission of COVID-19 has been observed during long-haul flights. In general, infections traced to travel tend to be passengers or workers who are in proximity to the index patient. For example, during a roughly 10-hour flight from London to Hanoi carrying 217 travellers that resulted in 14 infections among passengers and one among crew members, 12 of the infected were in the business class cabin where the index patient was located (Khanh, et al. 2020). Significant outbreaks have been associated with even sparsely occupied planes, as in the case of a flight to Ireland that yielded 13 in-flight cases – 12 passengers and one crew member - even though it was only at 17% capacity with 49 of 283 seats filled (Murphy, et al. 2020). In this case, there were several groups of infected travellers in adjacent seats. While these incidents suggest close contact transmission because of the clustering of cases, investigations of other incidents suggest airborne transmission. For example, during a 100-minute round-trip by bus to a religious event, 24 of 68 passengers were infected by a single index patient. The air conditioning system on the bus was in recirculation mode during the trip, i.e., no outdoor air was being brought in to dilute air contaminants (Shen, et al. 2020). In the case of the Diamond Princess Cruise ship incident, in which 712 of 3711 passengers and crew members contracted COVID-19, one analysis of infection data concluded that long range aerosol transmission accounted for most of the cases, even though the HVAC system on the ship was not recirculating air, while a second implicated close contact (Xu, et al. 2020).

Like most buildings, our means of transportation have not been designed to protect us from the risk of airborne infection. Aircraft, with their well-maintained systems that provide good ventilation and filtration of air still have proved vulnerable to infection transmission because of passenger density and the long duration of some flights. Other transportation modes provide greater opportunities to transmit disease to passengers and workers because of their designs that provide only modest ventilation and filtration and that may not be subject to the stringent maintenance requirements of aircraft. The COVID-19 pandemic has exposed the extent of these limitations as documented in forensic studies of transportation-related outbreaks. For the present, the best way to minimize infection risk related to travel remains to do so only when necessary and, even then, by observing all recommended safety and hygiene measures, particularly distancing and use of masks.

For the safety of those who must travel, it may be possible to upgrade the HVAC systems of some modes of transportation by improving ventilation, increasing filter efficiency and adding air cleaning technologies where applicable. However, as noted previously, there are limitations to the kind and extent of upgrades. This lesson – that risk can be significant and that our transportation systems currently may not provide the desired level of protection to workers and passengers, should be reflected in the design of future trains, buses, automobiles and ships. Improvements could include the obvious measures of increasing ventilation rates and filter efficiencies as well as making use of emerging air cleaner technologies. Some of the technologies we need are available now, but there are many opportunities for applied research to improve system design. Providing isolated, clean environments for workers is also important, given the higher level of risk they experience due to spending a much greater amount of their time exposed to the risks inherent in transportation. Clear instructions to passengers regarding safe travel practices that are enforced is also a way to make existing transportation system safer while new and better protected fleets are developing. Given the rate at which vaccines for COVID-19 are being deployed, follow through in addressing all of these needs is essential. ASHRAE is committed, within its sphere of expertise, to helping ensure that the safest possible conditions are provided for all who need and want to travel, today and in the future.

I appreciate the committee's desire to investigate this important topic and your consideration of my testimony. Protecting transportation workers and passengers is vital, especially for essential workers and those with critical needs such as doctor appointments. I hope my perspective focused on the built environment and HVAC systems proves useful, and I look forward to answering your questions. I also would be happy to provide any additional technical assistance from ASHRAE's Epidemic Task Force to advance the work of this committee. Thank you. ■

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Endnotes

[1] February 4, 2021: introduction to the testimony: Thank you for the opportunity to address the committee today. I appreciate that Chairman DeFazio and Ranking Member Graves recognize the importance of transportation worker and passenger safety as the COVID-19 pandemic continues to threaten health and life worldwide. I also want to thank the leadership of this committee for their foresight in holding a hearing on this topic last summer when few imagined that the worst days of the pandemic lay ahead. Today, COVID continues to take a terrible toll, so it is more important than ever to understand the tools available to us to reduce risk of disease transmission in aircraft, ships, trains, and buses, as well as the stationary facilities that support transportation. The lessons of this unprecedented public health crisis must be applied upon now to reduce case numbers and save lives, and absorbed so we will be better prepared to confront future epidemics that threaten our lives and livelihoods.

This testimony can be viewed: https://transportation.house.gov/committee-activity/hearings/protecting-transportation-workers-and-passengers-from-covid-gaps-in-safety-lessons-learned-and-next-steps

[2] www.ashrae.org/technical-resources/transportation

[3] www.ashrae.org/file%20library/technical%20resources/covid-19/core-recommendations-for-reducing-airborne-infectious-aerosol-exposure.pdf