Shaping Tomorrow's Built Environment Today

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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.

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 (Attachment A). 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 (Attachment B) 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 traveler 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 travelers 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 travelers 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. For the safety of workers, 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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ATTACHMENT A

ASHRAE Epidemic Task Force Guidance on Transportation

This ASHRAE guidance document is based on the evidence and knowledge available to ASHRAE as of the date of this document. Knowledge regarding transmission of COVID-19 is rapidly evolving. This guidance should be read in conjunction with the relevant government guidance and available research. This material is not a substitute for the advice of a qualified professional. By adopting these recommendations for use, each adopter agrees to accept full responsibility for any personal injury, death, loss, damage or delay arising out of or in connection with their use by or on behalf of such adopter irrespective of the cause or reason therefore and agrees to defend, indemnify and hold harmless ASHRAE, the authors, and others involved in their publication from any and all liability arising out of or in connection with such use as aforesaid and irrespective of any negligence on the part of those indemnified.

ASHRAE EPIDEMIC TASK FORCE

TRANSPORTATION | Updated 11-20-2020

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Disclaimer

Introduction

- Transportation and the facilities that serve them have become increasingly important and present in an increasingly global society.
- Looking at air travel alone, the number of passenger boardings have increased roughly 40% over the last 20 years.
- With this increase, the importance of air travel to us as individuals and our economy has continued to increase.
- The degree to which travelers are able to move around the globe has without a doubt contributed to the severity of the current pandemic.
- It is therefore crucial that infection control measures be taken wherever possible to break transmission paths and slow the spread so that our medical systems are not overwhelmed.

Introduction (cont'd)

- Public transportation is an activity that typically brings large numbers of people together and places them in close contact with each other.
- This has an overall effect of increasing the potential number of microbes present in the space as well as increasing the number of people exposed in that same space.
- There are also numerous commonly touched surfaces such as handrails, fare boxes, seats, doors etc.
- Increasing the number of people in a given space increases the chances that one of them may be an infected person.
- It is now known that infected persons may be asymptomatic or have very mild symptoms and are still able to infect others. Given this, even rigorous prescreening of passengers is unlikely to be 100% effective and transportation has the potential to be a major factor in disease spread going forward.

Introduction (cont'd)

- The easiest way to avoid becoming infected while traveling is to not travel in the first place.
- Many essential workers, especially in urban areas, require the use of public transportation systems, so bus, rail, and even air travel should only be embarked upon if it will not interfere with travel of essential workers.
- Should travel be contemplated, it is vitally important to follow public health official's recommendations in all places that are visited. This will reduce risks for all involved.

Introduction (cont'd)

- To this end, ASHRAE is presenting the following guidance for the transportation heating, ventilation and air conditioning (HVAC) industry.

- Note that the airline industry typically refers to environmental control systems (ECS), and this term is used interchangeably with HVAC systems.

- The list presented here is not intended to be exhaustive and recommendations will potentially change as science learns more about the virus, and as medical officials change their directives based on local situations as they evolve.

- Guidance is broken out into mode-specific guidance for various participants in the process and then guidance for transportation facilities.

Guidance for Mass Transit Riders

- Much of the virus transmission on transportation vehicles is directly from person to person, so maintaining space between people as much as possible is recommended. Spacing of occupants also helps HVAC do its job.
  - Passengers should be aware that some virus may linger in the air and on surfaces.
  - Ventilation air is filtered and while most ground transportation vehicles have high grade filters, most systems do not have and may not be able to be equipped with high efficiency filters (e.g. HEPA filters) which would filter out all viruses.
  - Filters cannot clean the air from the passenger compartment that has not been returned to the filter yet or air that bypasses the filter though leakage in the ducting.

Guidance for Mass Transit Riders (cont'd)

- A high-quality mask such as N95 or KN95 rating will greatly reduce the transmission rate.
  - Where shortages exist, such high-quality masks should be reserved for health care workers and other first line responders where they can do the most good.
  - Lesser quality masks may still offer some protection for the general public and have been recommended for use by some public health officials.
  - Glasses or goggles will help block droplet transmission.
  - Use hand disinfectant while on the vehicle if possible and disinfect or wash hands as soon as possible after disembarking.
  - Avoid touching your face and eyes and follow your local health official's guidelines.
  - Additional mask-related guidance is available from the CDC.

Guidance for Mass Transit Riders (cont'd)

- When using a vehicle restroom, wait for a few minutes with the door closed after the previous user exits to allow ventilation systems to clear the air.
- After using, flush with the lid down and exit promptly.
- Again, wash or disinfect your hands when leaving, using proper handwashing techniques.
- Position yourself as far away from other people as possible.
- Follow the transit operator guidelines.

Guidance for Mass Transit Operators, Rail and Bus

- Mass transit operators include public transportation organizations, school systems, commercial shuttle operators, and other entities that operate vehicles that transport larger numbers of passengers

- Mass transit operations present an especially challenging environment because of the very high occupant density in a fully loaded vehicle.
  - People are typically seated immediately adjacent to each other and in some cases may be standing very close together in a confined space.
  - Vehicle motion will often require the use of hand holds and straps creating common touch surfaces.
  - The situation is further complicated by a wide variety of HVAC systems being present across the industry.
  - Air conditioning and heating may or may not be present depending on location. Windows may be or may not be operable.
  - Vehicles may have high ventilation rates which remove airborne droplets quickly and minimizes the duration of the exposure from a one-time release (e.g. a cough).

Guidance for Mass Transit Operators, Rail and Bus (cont'd)

- Demand controlled ventilation is typically not present but is slowly coming into use to afford energy savings.
  - Where present such systems should be adjusted to provide maximum ventilation flows consistent with the vehicle manufacturer's recommendations.
  - Ventilation may be independent of any recirculation of vehicle air or it may be directly coupled by virtue of a common fan.
  - Vehicle operators may have completely independent air handling systems, more typical in the rail environment, or they may share vehicle air with passengers.
  - For these reasons uniform guidelines are extremely difficult to generate and the basic principle of consultation with manufacturers prior to making design changes should always be followed.

Guidance for Mass Transit Operators, Rail and Bus (cont'd)

- Shutting off HVAC systems in vehicles is NOT recommended because there is no outside air introduction and no air purging.

- When conditions allow and it will not create safety and passenger comfort issues, the opening of operable windows is an option on some buses (e.g. most school buses) that can greatly increase the flow of air.

Guidance for Mass Transit Operators, Rail and Bus (cont'd)

- Changing to high efficiency (e.g. HEPA) filters would potentially improve the removal of viruses from the passenger compartment, but this change could damage the HVAC equipment and void the warranty.
  - Any filter type change should be coordinated with the system manufacturer and be sure that before and after total air flow is acceptable.
  - Reduced air flow can cause coil icing, imbalanced/insufficient air flows, and upset overheat protection device operations.
  - Additional information is available in the guidance on filtration.

- Good maintenance practices should be followed with regard to filter replacement.
  - Be sure that filters have not been left out and that they are not overdue for replacement.
  - Return air grills and diffusers should be cleaned regularly.
  - Following exposure to a suspected or confirmed COVID-19 positive individual, filters should be replaced as part of an overall vehicle deep cleaning procedure.

Guidance for Mass Transit Operators, Rail and Bus (cont'd)

- UV-C light is used as a disinfecting agent in numerous applications but is not recommended in this application.
  - In order to be effective pathogens must be exposed for proper durations.
  - Thus, UV-C can be used to prevent growth on static surfaces such as filters, coils etc. where residence times are lengthy.
  - UV-C light can also cause break down of photosensitive materials and is potentially harmful to humans if they are directly exposed.
  - Retrofitting of UV-C lights is therefore not to be taken lightly, and installation must be done according to the vehicle manufacturer's recommendations only as part of a formal redesign effort.
  - If already present, correct operation should be verified for maximum benefit.

Guidance for Marine Passengers

- Marine passengers are in very much like a typical hotel setting. As such, distancing measures are more easily accomplished than in other modes of transportation.

- However, the duration of the stay is typically greatly increased relative to other modes of transport and this creates different challenges.

- In general, follow the medical officer’s advice.

- Stay isolated as much as possible, avoid touching common surfaces as much as possible, do not touch face and eyes, and do frequently wash hands.

- Large cruise ships will generally already have in place response procedures for infection control.

- Follow the direction of the ship’s personnel in such situations.

Guidance for Marine Passengers (cont'd)

- If weather permits open windows or exterior doors if present to increase ventilation.
- Do not prop open interior berth doors to the hallways as unfiltered air exchange with common areas should be avoided as much as possible.
- Avoid standing or sitting for prolonged periods in drafty locations such as directly in line with air vents and diffusers.
- Do not interfere with air handling equipment such as blocking of vents with towels.

Guidance for Marine Operators

- The marine environment is quite different from other modes of transport in that passenger density is likely less, but also that duration of transport is significantly longer, on the order of days or weeks.

- The opportunity for social distancing is greater, but the time factor increases opportunity for infection if it is present.

- Humidity is an obvious concern in maritime HVAC designs.

- We have not directly considered military ship operations although some of the principles may apply.

Guidance for Marine Operators (cont'd)

- Hotel guidance measures can be found at the following websites produced by the government of Alberta and by the World Health Organization (WHO).
  - COVID-19 Public Health Recommendations for Hotels, Hostels, and Inns
  - Operational considerations for COVID-19 management in the accommodation sector

- It is expected that these protocols will closely resemble those already in place for generalized and specific infection control aboard ships.

Guidance for Marine Operators (cont'd)

- Marine HVAC applications often have relative humidity (RH) controls not present in other modes of transport.
  - Normally RH is set low enough to inhibit mold growth.
  - Bacteria also demonstrate reduced viability at low humidity levels vs high humidity.
  - However, it has been shown that some viruses decay more rapidly at intermediate humidity's, between 40 and 60% RH.
  - Further studies cite an RH of 50 to 55% RH is not only beneficial to reduced viral transmission but is also enhancing the immune response to infection.
  - It would be wise to ensure that system humidifiers are operational, and that their set-points be increased, within the vehicle manufacturer's recommended window, towards the 50 to 55% RH target.

Guidance for Marine Operators (cont'd)

- Some marine HVAC plants allow for balancing of outside air vs recirculation.
  - Increasing outside air and minimizing recirculation, within the system manufacturer's tolerances, will reduce the risks of recirculation of pathogens within the ship.
  - Total elimination of recirculation may not be possible.
  - As marine journeys can be lengthy, passenger comfort is correspondingly more important than in many other modes of transport where trip durations can be significantly shorter and lack of comfort may be more tolerable.

Guidance for Marine Operators (cont'd)

- Filtration of both outside air and any recirculated air is important.
  - Filters may have been removed or forgotten at some point in time.
  - Ensure that proper filters are installed in all air handling units, and that installation techniques are followed.
  - In some cases, this may include taping of joint areas to prevent bypass.
  - Do NOT replace lower performance level filters with higher performance level filters without consultation with the original equipment manufacturer.
  - High efficiency filters typically have greater pressure losses and this may compromise air distribution and reduce air flows to the point of creating alarm conditions.
  - This can include freezing of coils, over heating safeties on heating systems, flow switch trips etc., which may cause equipment damage and void manufacturer's warranties. Increasing filtration efficiency, if undertaken, should be considered as any other major redesign would be, and planned carefully by experts in the field and executed as a formal refit.
  - Additional information is available in the guidance on filtration.

Guidance for Marine Operators (cont'd)

- UV-C light is used as a disinfecting agent in numerous applications.
  - In order to be effective pathogens must be exposed to UV-C for proper durations.
  - UV-C can be used to prevent growth on static surfaces such as filters, coils etc. where residence times are lengthy.
  - UV-C light can also cause break down of photosensitive materials and is potentially harmful to humans if they are directly exposed.
  - Retrofitting of UV lights is therefore not to be taken lightly, and installation must be done according to the vehicle manufacturer's recommendations only as part of a formal redesign effort.
  - If already present, correct operation should be verified to achieve maximum benefit.

Guidance for Air Passengers

- It is recommended that passengers wear face masks.

- There are good reasons unrelated to the Environmental Control Systems (ECS) for wearing face masks (e.g. potential reduction of person-to-person transmission). However, they also work with the ECS to reduce the risk of transmission.

- First, the face mask will catch some of the virus containing droplets and prevent them from getting into the air.

- The ventilation system starts with a lower droplet load and the resulting concentrations will be proportionately lower as the ventilation removes some of the remaining droplets.

- Those droplets that do escape the mask and the associated air will have much less momentum especially in comparison to uncovered cough and sneezes. This lower momentum reduces the initial spread of the viruses and enhances the ability of the ECS to remove them before they spread as far as they would otherwise.

Guidance for Air Passengers (cont'd)

- Personal air outlets (PAO) do not appreciably increase total airflow to the cabin, typically about 2 cfm (0.9 L/s) when fully open per PAO.
- In some designs the PAO flow is offset by reductions in the main air supply flow.
- The PAO is supplied from the mix manifold on most aircraft and, thus can be expected to provide virus free air at the nozzle.
- The jet of air generated entrains cabin air and by the time it reaches the breathing zone it is mostly cabin air.
- Thus, PAOs do not provide an "air shield" that protects the passenger from viruses in the air. Laboratory studies have shown that PAO use can increase or decrease exposure depending upon the location of the infected person and other factors.
- While it is difficult to predict the effect for a given seat on a given aircraft, laboratory studies show that, on the average, PAOs do provide some modest reduction of exposure.
- It is not necessarily recommended that all passengers use PAOs but their use should not be discouraged.

Guidance for Air Operators

- Aircraft cabins present an especially challenging environment because of the very high occupant density in a fully loaded aircraft.

- People are seated immediately adjacent to each other for extended periods of time in a confined space.

- However, aircraft cabins have high ventilation rates which remove airborne droplets quickly and minimizes the duration of the exposure from a one-time release (e.g. a cough).

- The details of the aircraft ECS vary somewhat between makes and models but the general design is similar for nearly all airline aircraft.

Guidance for Air Operators (cont'd)

- Outside air from the air-conditioning packs flows to a central mix manifold.
  - Additionally, cabin air from the cabin exhaust is supplied to the mix manifold after passing through filters.
  - Air from the mix manifold is then distributed throughout the cabin using one or more linear air supply diffusers that run the length of the cabin.
- Essentially all airline aircraft use HEPA filtration on the recirculation air.
  - HEPA filters have demonstrated good virus removal efficiency; however, the ability of the HEPA filters to remove viruses and other particles is directly related to the airflow through the filter.
  - Aircraft with HEPA recirculation filters should be operated with the Recirculation System ON in order to maximize the filtration of cabin air, according to the aircraft manufacturers specifications.
  - Additional information is available in the guidance on filtration.

Guidance for Air Operators (cont'd)

- Aircraft design, modification and operation are highly regulated and even minor modifications require expensive and time-consuming regulatory approval.

- Additionally, the systems are highly engineered and integrated and any modifications require extensive engineering analysis and testing.

- For these reasons, **modifications to aircraft ECS are NOT recommended as a short-term response to COVID-19 concerns and emphasis is therefore on operation measures that can be taken.**

Guidance for Air Operators (cont'd)

- First and foremost, the aircraft ECS should be maintained and tested to ensure that all components are functioning properly and performing as designed.

- Any problems with the ECS that may reduce airflow will reduce its effectiveness in mitigating disease transmission.

- It is important that the cabin is, not only, supplied an appropriate amount of ventilation air but that it is also distributed uniformly throughout the cabin.

- Air flow measurements should be made along the length of the cabin to confirm that air is being properly distributed and corrective action taken where indicated.

Guidance for Air Operators (cont'd)

- ANSI/ASHRAE Standard 161-2018, *Air Quality within Commercial Aircraft*, specifies a minimum of 15 cfm (7.1 L/s) per person of supply air in flight and recommends 20 cfm (9.4 L/s).

- Aircraft ECSs are designed based on a fully loaded cabin.

- Even though these requirements may be met with reduced airflow to the cabin when partially loaded, it is recommended that the ECS be operated at fully loaded design flows even when partially loaded to obtain the maximum benefit from the ventilation and reduced loading.

Guidance for Air Operators (cont'd)

- Certain normal operations require the ECS to be shut down or at least the outside air source to be shut off when passengers are onboard, e.g. engine starting, de-icing, switching to ground source air, etc.
  - Because of the confined space, contaminants in the air including droplets containing viruses if a source is present, can build up quickly when there is no ventilation. Even 5 minutes without an operating ECS can result in substantial increase in air contaminants.
  - ASHRAE Standard 161-2018 specifies that these periods be kept as short as feasible. In response to COVID-19 concerns, extra vigilance should be exercised to minimize the time the ECS is shut down when the cabin is occupied.
  - When feasible, the ECS should continue to be operated in recirculation mode when outside air must be shut off.
  - ASHRAE Standard 161-2018 specifies 30 minutes as the maximum time the ventilation can be shut off or reduced when the cabin is occupied.
  - Much shorter limits should be observed in response to COVID-19 concerns to the extent feasible.

Guidance for Air Operators (cont'd)

- Any operation with reduced ventilation airflow should be avoided.
  - For example, if single pack operation results in reduced airflow, it should be avoided even when allowed by regulation.

Guidance for Air Operators (cont'd)

- Distancing (e.g. empty seats between passengers) is likely to be employed for non-ECS related transmission mitigation such as direct contact and surfaces.
  - These measures will also enhance the ability of the ECS to reduce droplet concentrations from an infection source before they reach other passengers.
  - However, distancing alone is unlikely to eliminate airborne exposure.
  - Laboratory measurements and limited infection data from aircraft indicate airborne exposure can occur for several seats in all directions, front and back, right and left, from an infected person.
    - In one documented flight with SARS transmission, an infection occurred 7 rows in front of the source persons.
    - However, the probability of infection dropped off rapidly with distance from the source person.
    - Laboratory measurements, modeling studies, and infection data, show that the highest risk location is the seat immediately in front of the source.
    - If empty seats are used to increase spacing, staggered seating should be considered to avoid placing people directly in front of one another.
    - These data are all based on no face mask being worn.
    - It is not known how the use of a face mask might affect the results, but it is unlikely that staggered seating would have any negative effect on exposure.

Guidance for Air Operators (cont'd)

- It is likely that airlines will adopt loading and deplaning procedures that will minimize passenger mingling, e.g. back to front loading.

- The benefits of these procedures are enhanced by the nature of the aircraft ventilation.
  - Passengers will walk through unloaded portions of the aircraft, and thus through more-or-less contaminant free air, on the way to and from their seats.
  - Once at their seats, they will be in comparatively close proximity only to the same passengers that will be in close proximity the rest of the flight.

Guidance for Air Operators (cont'd)

- Data have shown the relative humidity in the range of 40%-60% results in the most rapid decline in airborne virus viability.
  - In flight, relative humidity in aircraft cabins is typically below 30%.
  - The vast majority of airline aircraft do not have humidification capability.
  - If it is available, increasing the humidity may provide a benefit.
  - Any humidification should observe aircraft manufacturer guidance as elevated humidity in aircraft cabins has the potential to create safety concerns unrelated to disease transmission.

Guidance for Air Operators (cont'd)

- Airlines should already have guidelines and procedures in place to handle situations where passengers become ill during a flight.
  - These include documentation of all passenger locations, isolation of the sick passenger if possible, offering of masks to the sick person and to persons seated near the infected person if moving of passengers is not possible or limited.
  - In no case should the ECS be turned off.

Guidance for Transportation Facility Operation

- There are two very important differences between transportation facilities and other similar commercial buildings (office buildings, malls, etc.).
  - First, the occupants of the facility are often on their way to or have come from other locations (other neighborhoods, cities, states, and countries). This means that transportation facilities can be viewed not only as a point of entry for people and/or goods new to territory but also as a potential point of entry for infections that the infections that travelers may carry.
  - Second, the facility may be subject to a great deal more regulation. This difference is particularly acute for facilities that are related to international travel, as the operation of all or parts of the facility may be controlled by security concerns. Many facilities operate in the intersecting governance of various local, state/provincial, and national governing agencies or bodies. Additionally, the facility may have tenants (operators of the transport services using the facility) that are subject to regulation by a different set of agencies or bodies.

- Taken together, these two differences mean that the most important piece of guidance, which will be repeated below, is that transportation facilities always need to operate in close cooperation/coordination with the appropriate local, state/provincial, and national health authorities.

Guidance for Transportation Facility Operation (cont'd)

- ASHRAE's position document on infectious aerosols suggests that facilities should have emergency plans to mitigate the impact of infectious aerosols.
  - If the facility does not have a plan, the position document provides guidance on items that should be considered for implementation in situations like this.
  - Handling of ill passengers is particularly important.
  - WHO has interim guidance available.

Guidance for Transportation Facility Operation (cont'd)

- Many transportation facilities have a variety of usage types.
  - Consult the ASHRAE guidance on similar buildings to the facility under consideration.
  - If, for example, the facility has a building or buildings with significant office space usage, consult the commercial buildings guidance for more information on the operation of systems that serve those spaces.

Guidance for Transportation Facility Operation (cont'd)

- While it is tempting to make changes to HVAC system operation that superficially seem beneficial, it is important that HVAC systems be operated as intended/designed.
  - This is particularly important for facilities that have been viewed as potential targets by malicious actors.
  - Any changes to HVAC system operation should only be done in consultation with experts with the appropriate licensing, certification, or qualification.

Guidance for Transportation Facility Operation (cont'd)

- As long as proper professional guidance is sought before making an intervention, there are low complexity interventions available:
  - Verify that systems are working properly (while being cognizant of potential hazards). While a full commissioning exercise might not be warranted, no larger interventions should be made without first verifying that the current system is operating as designed, particularly with respect to filtration and outdoor air.
  - Increasing filtration to higher efficiency filtration is a lower complexity intervention that may have appreciable impact. ASHRAE has made separate guidance available on filtration and filtration systems.
  - Consider additional air and surface disinfection options, particularly in waiting areas where passengers may spend more time. Options include installation of upper-air UV-C systems and the use of roll-in UV-C disinfection systems. Beware, however, that UV-C is known to cause degradation in materials that are exposed in the longer term.

Guidance for Transportation Facility Operation (cont'd)

- As noted elsewhere in this guidance, social distancing inside vehicles helps the onboard HVAC equipment do its job better. It is therefore incumbent upon the facility to support distancing as much as possible.
  - Many passive mechanisms are available to reinforce the importance of distancing that help travelers distance themselves from other travelers and workers in the facility.
  - Providing rope lines to maintain order in boarding areas will help passengers space themselves, particularly if there are longer wait times
  - Tape on the floor can assist with guidance on appropriate spacing between passengers while waiting to board trains.
  - Social distancing inside the vehicles may require that schedules be changed to better accommodate passenger volume, so it is important for facilities to be flexible in this regard.

Guidance for Transportation Facility Operation (cont'd)

- A consequence of the current pandemic is that some modes of transportation (e.g. air travel) are experiencing greatly reduced use.
  - Consider closing down areas that are not required for passenger use, and as passenger counts diminish, to reduce the areas that have to be cleaned and sanitized regularly.
  - This may also allow building operators to reduce the amount of HVAC equipment being run which serve areas that are not in use, but care should be taken as operational schedules are changed so that reduction in use does not damage systems.
  - Further information is available in ASHRAE's guidance on shutdown/startup of buildings and systems.

Guidance for Transportation Facility Operation (cont'd)

- Transportation facilities are the source and destination of travel of humans, goods, and any infections that they might carry.
  - It is therefore vitally important that operators coordinate with national, state/provincial, and local health authorities to make sure that the procedures used and any operational decisions that are made are in keeping with the most current guidance.

Disclaimer

This ASHRAE guidance document is based on the evidence and knowledge available to ASHRAE as of the date of this document. Knowledge regarding transmission of COVID-19 is rapidly evolving. This guidance should be read in conjunction with the relevant government guidance and available research. This material is not a substitute for the advice of a qualified professional. By adopting these recommendations for use, each adopter agrees to accept full responsibility for any personal injury, death, loss, damage or delay arising out of or in connection with their use by or on behalf of such adopter irrespective of the cause or reason therefore and agrees to defend, indemnify and hold harmless ASHRAE, the authors, and others involved in their publication from any and all liability arising out of or in connection with such use as aforesaid and irrespective of any negligence on the part of those indemnified.

ATTACHMENT B

ASHRAE's Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

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ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

1. *Public Health Guidance* - Follow all regulatory and statutory requirements and recommendations for social distancing, wearing of masks and other PPE, administrative measures, circulation of occupants, reduced occupancy, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   - 2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   - 2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   - 2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   - 2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

4. *HVAC System Operation*
   - 4.1 Maintain temperature and humidity design set points.
   - 4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   - 4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   - 4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outside air intakes, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*