ASHRAE EPIDEMIC TASK FORCE

TRANSPORTATION | Updated 11-20-2020

Introduction
- Overview

Guidance for Mass Transit Riders
- Person to Person Contact
- Masks
- Other Recommendations

Guidance for Mass Transit Operations, Rail and Bus
- Challenges
- Demand Controlled Ventilation
- HVAC and Windows
- Filter Replacement
- UV-C

Guidance for Marine Passengers
- Procedures
- Ventilation and Air Distribution

Guidance for Marine Operators
- Considerations
- Relevant Hotel Guidance
- Humidity Controls
- Outside Air vs. Recirculation
- Filtration
- UV-C

Guidance for Air Passengers
- Face Masks
- Personal Air Outlets (PAO)

Guidance for Air Operators
- Considerations
- Outside Air and Filter Replacement
- Modifications
- Shutdown of the ECS
- Avoiding Reduced Ventilation
- Social Distancing
- Loading and Deplaning Procedures
- Humidity
- Emergency Procedures

Guidance for Transportation Facility Operation
- Considerations
- Emergency Plan
- Building Types
- Changes to HVAC Operation
- Social Distancing
- Reduced Facility Use

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.