ACI-NA Airport Industry Recovery Issue Briefing: Mitigating COVID-19 Transmission Risks through Modifications to Existing HVAC Systems

Issue Summary

Improving airport facility indoor environments to reduce the spread of disease can support the health of Airport passengers and employees and reassure building occupants that the Airport has taken industry recommended measures to improved building occupant health, comfort and safety. Airport heating, ventilation, and air conditioning (HVAC) systems can play a vital role in reducing airborne transmission risks of COVID-19 and other pathogens. To help airport operators, ACI-NA has developed this issue briefing, which discusses actions airport operators can take to mitigate COVID-19 transmission risks through assessment, maintenance and modifications to their existing HVAC systems. These actions were evaluated based on ease of implementation and given classifications. Immediate actions are those that can be performed immediately with airport staff. Short term actions may require some assistance from outside vendors which could include procurement activities. Long term actions can be planned so that resources can be properly allocated.

Summary of Current Industry Guidance

There are multiple sources of information on mitigating the risk of COVID-19 transmission through modifications to existing HVAC systems including: a) Center for Disease Control and Prevention (CDC), b) American Industrial Hygiene Association (AIHA), c) Building Owners & Managers Association International (BOMA), d) Environmental Protection Agency (EPA), and e) the World Health Organization (WHO)[1]. Most of the guidance from these sources references the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA).

All of these sources cite that the most effective way to reduce transmission of COVID-19 is proper cleaning of surfaces and minimizing transmission of airborne pathogens. Important for every epidemic are the transmission routes of the infectious agent. In relation to COVID19 the standard assumption is that the following two transmission routes are dominant: via airborne droplets (particularly very fine aerosol particles emitted when sneezing or coughing) and via surface (fomite) contact (hand-hand, hand-surface, etc.). This issue briefing will focus on the mitigation of airborne aerosol droplets/particles transmission.

ASHRAE's statement on airborne transmission of SARS-COV-2/COVID-1[2]

> "Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures."

ASHRAE's statement on operation of heating, ventilating, and air-conditioning systems to reduce SARS-CoV-2/COVID-19 transmission[2]

> "Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air. Unconditioned spaces can cause thermal stress to people that may be directly life threatening and that may also lower resistance to infection. In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus."

Indoor environments can play a role in the health and well-being of passengers and airport/airline/concession/contractors' staff. Research has shown that the Indoor Environmental Quality, and in particular, indoor air quality can have a direct impact on human health, safety, productivity and comfort as well as business critical asset-protection and subsequent energy consumption of those assets. Poor outdoor air quality, poor outdoor air filtration and poor temperature and humidity control can lead to increased infectivity of pathogens, causing illness in human beings.

ASHRAE and REHVA guidance summary is noted in the Good Practices section of this document[3,4].

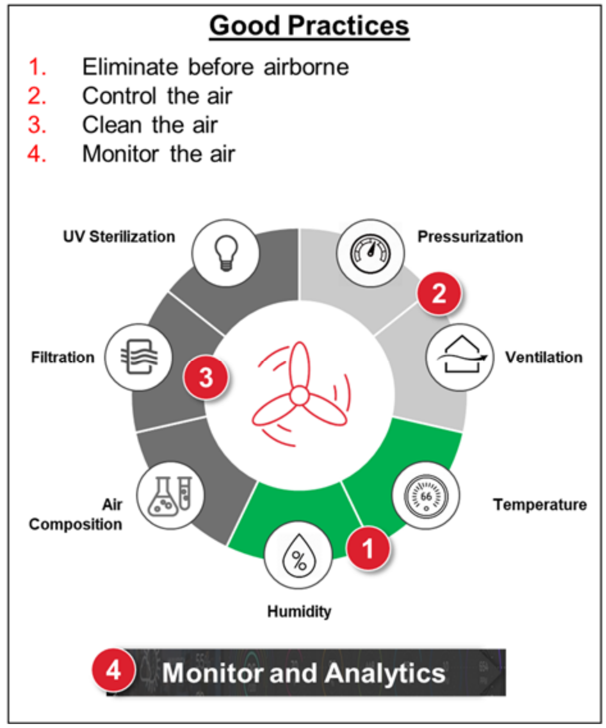
At the time of this publication, there is a growing number of scientists that are studying the probability of COVID infection through airborne transmission. To date, it is believed that people are infected by contacting surfaces that contain COVID. However, there is evidence that might indicate that "there is significant potential for inhalation exposure to viruses in microscopic respiratory droplets… at short to medium distances."[5] This means that COVID can spread through the air as an aerosol without anyone needing to cough or sneeze. An aerosol is a microscopic virus-packed particle that's also expelled from an infected person's mouth when breathing, speaking, coughing or sneezing. Unlike a droplet, smaller aerosol particles can remain suspended in the air.[6] If infection is possible through airborne transmission, it further accents the requirement to understand the effect ventilation and HVAC systems have on COVID infection rates.

It should also be mentioned that there are a few studies available with evidence supporting the transmission of COVID-19 in fecal matter.[7] These studies were conducted in the early stages of the pandemic and with limited patient numbers. The transmission path is not fully understood, and further research is warranted. Precautions should be taken to help protect passengers and employees. Wearing of proper personal protective equipment (PPE), increasing the cleaning cycle of bathrooms, and washing hands after using the toilet should be measures implemented to reduce this possible transmission path. It is also recommended that airport maintenance staff are trained in the appropriate cleaning methods for bathrooms.

Good Practices for the Operation and Maintenance of Existing HVAC Systems in Light of the COVID-19 Pandemic

Good practices are aimed towards minimizing transmission of pathogens through the air. These practices can be grouped into four broad categories:

1. **Keep particles from becoming airborne**: When an infected passenger or airport employee coughs or sneezes, droplets are expelled into the air. The large droplets fall to the surface, within 6 feet of the infected person. The smaller particles can become airborne and stay airborne for hours. The humidity and temperature of the air effect the duration and distance particles can travel in air. Proper humidity and temperature controls are important to minimize the spread of airborne particles.



2. **Control the air**: Air flow through the terminal can be controlled to minimize recirculation of air and harmful pathogens, and to manage recommended levels of air changes per hour based on occupancy, outside air ventilation, and zone pressurization.

3. **Clean the air**: Pathogens that become airborne can be cleaned through various filtration methods including MERV (minimum efficiency reporting value) and HEPA (high efficiency particulate air) air filters, Electronic and Ultraviolet Light air cleaning methods.

4. **Monitor the air –** Data points for HVAC systems can be set for continuous monitoring to detect problems prior to impacting indoor air quality (IAQ). These may include air flow, air changes per hour, filter status, directional pressure, temperature, relative humidity (RH), carbon dioxide (CO_2), volatile organic compounds (VOC), particulate matter (PM2.5), formaldehyde (HCHO) and others.

Indoor Air Quality Plan to control the impact of COVID-19

Traditional HVAC design and control strategies lean more towards the energy conservation and operational efficiency. This at times, come at the compromise of thermal and IAQ parameters. In contrast, the reduction of COVID infection rates emphasize the importance of indoor air quality. Three key components of a proper IAQ strategy are: 1) the adequate distribution and ventilation of air including proper outside air introduction, 2) the control of airborne contaminants through filtration and cleaning, and 3) proper humidity and temperature control for the reduction of infectivity of pathogens and the comfort of humans.

A COVID IAQ strategy can include immediate, short term and long-term actions.

1) Immediate Actions – Confirm HVAC systems have been properly maintained and a continuous maintenance program is in place. Make sure these systems are optimally working to positively impact occupant health. Areas of focus for maintenance and quick turn actions include regular filter replacement, cleaning the coils, checking proper operation of AHU fans, outside air dampers, and heat recovery systems. Where possible set temperature, humidity and pressure set points as per system design and/or ASHRAE 62 Standards.

a) To keep particles from becoming airborne, ensure that the temperature set point is at the optimal setpoint for the facility and for the control of humidity. Keep humidity between 40% to 60% RH. Viruses remain active longer and are more prone to travel through the air at lower humidity rates. Above 60% RH, transmission rates increase initially, then decrease at higher RH levels due to droplets falling out of the aerosol.[8]

b) Identify the location of HVAC return air vents. Determine if they are susceptible to the ingestion of particles. Any return air vents that are in close proximity to people congregating should be protected. Use stanchions, signs and barriers to keep people a safe distance away from return air vents. As for a safe distance, consider lengths beyond the current CDC 6 feet guidance. There are varying reports that try to determine the spread of a human cough. Several cite researchers measuring distances up to 12 feet with the potential to reach 20 feet and stay airborne for 10 minutes.[9,10,11]

c) To control the quality of air in the terminal, increase outdoor air ventilation. With an expected lower population in airports post COVID, the effective dilution ventilation per person is increased. Increase ventilation rates by disabling demand-controlled ventilation (DCV). Open minimum outdoor air dampers, as high as 100% where HVAC design permits, thus reducing recirculation of the virus in the terminal. Consider the seasonal and geographical effects on terminal humidity and temperature levels as more outside air is introduced to interior spaces. Install air flow measuring stations outside of air ducts if not already present. Mixed damper control for the air handling units should be modified through the Building Management System (BMS) to disable demand ventilation control and to include dilution ventilation. ASHRAE recommends using caution, while increasing fresh air intake in highly polluted areas. If the air outside is of poor quality, reconsider outside air intake practices.

d) Any strategies to control the air by increasing outside air rate should consider the presence of Volatile Organic Compounds (VOC's) in the airport as jet fuel is a large VOC component at airports. Investigate location of outside air intakes and verify that they are not in the vicinity of the ramp areas is recommended. Furthermore, wind direction and speed should also be checked so that VOC's are not being blown into air intakes.

e) Directional airflow can be controlled and initiated to help isolate sensitive areas, mitigating the risk of infectious aerosols from moving throughout the terminal. Create negative pressurized zones around critical areas such as passenger screening areas, restrooms, check points, and others that can become potential choke points. By maintaining the right pressurization, based on occupancy or risk sensitivity, the recommended amount of airflow can be delivered with optimal air change rates when needed. With this type of versatility and performance, energy savings can be achieved without unduly compromising the safety of the occupants.

f) HVAC and ventilation systems that serve high passenger flow choke points, such as passenger tunnels, trams, people movers, etc. should be included in any mitigation strategy. Increase control and cleaning of air in these areas will help offset the inability to maintain a safe social distance.

g) Use portable room air cleaners with HEPA filters to clean the air. Target high passenger traffic areas such as ticketing counters, security and passports, waiting areas, shops and restaurants, food courts, convenience facilities, departure lounges/gates, and baggage claim. Portable room air cleaners can also be used in staff rooms, crew rooms, and office areas.

h) To help keep air clean, upgrade AHU filters to minimum MERV 13, HEPA, or the highest filter rating compatible with AHU design. Seal edges of the filter to limit bypass. Monitor pressure drop across air filters in the air handling units to make sure they do not exceed setpoint. This filter monitoring is done through the BMS by installing pressure differential sensors connected to BMS controllers. As for HEPA filters, true HEPA filters are at least 99.97% efficient at filtering 0.3 μm mass median diameter (MMD) particles in standard tests. SARS-CoV-2 is approximately 0.125 micron in diameter[12] and HEPA filters captures particulate of 0.01 micron and above with extraordinary efficiency by diffusion and interception mechanisms[13]. Due to high pressure drops, HEPA filters may not be able to be retrofitted into HVAC systems. For that reason, electronic air cleaners with UV-C lighting in AHU's or portable air purifiers with HEPA filters could be considered[14].

i) For systems with automated controls, adjust the existing algorithm that controls fresh air to maximize where possible through the terminal. Monitor the indoor air quality using an existing or temporary IAQ monitoring system. Ensure there is not pollution or harmful VOC's that could be introduced into the terminal. Adjust the algorithm as required to address any concerns.

j) Maximize the availability of airport resources for aircraft cabin ventilation and cooling. This includes making airport preconditioned air (PCA) available for aircraft use. Operate the PCA units at the maximum allowed pressure/airflow to maximize aircraft ventilation. When PCA is not available, allow the use of aircraft auxiliary power units (APU) to alternatively provide ventilation and cooling to the aircraft. Operation and maintenance of aircraft cabin environmental control systems is outside of the scope of this document but is covered by existing guidance from EASA[15] and ICAO[16] and other resources.

2) Short Term Actions - Perform a detailed temperature, humidity, pressurization and IAQ controls audit to determine enhancements needed. Audit systems using emerging industry guidelines[1,2,3,4]. The audit may identify the need for additional sensors to monitor the IAQ of the airport.

a) Improve ventilation, air quality, temperature and humidity comfort by installing sensors as needed to equipment and filters to monitor humidity, CO^2, VOC's, and particulates.

b) To assist in managing areas of the terminal that are no longer in use, define "occupied" and "unoccupied" zones. Evaluate temperature, humidity, outside air rates, and light level settings and determine the appropriate set points and levels that correspond to the area's use. Reconfigure building automation and lighting control sequences to accommodate these different areas.

c) Increasing the amount of outside air into the terminal will have a negative effect on energy efficiencies. Optimization software for variable air volume (VAV) and dedicated outside air systems (DOAS) can be used to help offset this negative effect.

d) Provide IAQ dashboards that display air quality metrics. Dashboards can be for both maintenance/operation of airports and passenger data and likely have differing levels of detail. For maintenance and operations, dashboards can include detailed data on air quality, cleaning, and maintenance by zones and be used to identify when and what corrective actions are required. For passengers, dashboards can summarize overall air quality and cleaning status.

3) Long Term Actions – While implementing immediate actions, planning on long term actions should begin. There are multiple existing technologies that can be installed in terminals that help identify, manage, and reduce the actual COVID transmission paths.

   a) Consider implementing building re- or retro-commissioning processes to establish that airport that the HVAC and electrical systems are operating as intended. These processes are used to confirm energy efficiency and indoor air quality meet the airport's goals and standards.

   b) The installation of differential pressurized zones (negative or positive air flow pressure) can be used to help isolate spread of contaminated air generated in high risk spaces (negative) or used to maintain clean air (positive) to mitigate risk of hazardous air spreading into high traffic spaces. In addition, these HVAC indoor air quality improvements can be integrated with an air filtration system to deactivate viruses or kill bacteria. Areas to consider differential pressure strategies include terminal openings like entrances, passenger boarding bridges, TSA confinement spaces, restrooms and baggage tug areas where differential pressure should be maintained to help manage spread of contaminated air. Analytics can be applied to all sensors and systems to increase their effectiveness. Machine learning for HVAC systems can be used to make the most efficient control adjustments required for constant changing terminal conditions. Integrated advanced sensors that measure indoor and outdoor air quality can be added to existing controllers to monitor and control spatial air quality, humidity and temperature.

   c) To help clean air, consider retrofit solutions that wok within existing HVAC systems. These include use of ultraviolet (UV) light, electronic air cleaners, and bipolar ionization. Note that the effectiveness of these solutions varies based on specific HVAC system configurations and specifications and they are not appropriate for use in all cases. HVAC system design professionals should be consulted to assess the appropriateness of these approaches for use with a particular system.

      - UV-C in duct: Banks of UV-Lamps installed inside HVAC systems are generally focused on cleaning coils, drain pans and other wetted surfaces. Keeping the coils clean allows better heat exchange and lower maintenance, thus saving on energy and maintenance cost[17]. It could be impractical to expect the UV-C in duct to disinfect airborne pathogens with definitive claim in first pass contact, specifically because it requires high UV doses to inactivate microorganisms on-the-fly as they pass through the irradiated zone due to limited exposure time. Though it is not feasible to make definitive claim on first pass germicidal efficacy of UV-C lights in duct, it would have some positive effect on microbial loads in the space in multiple passes apart from giving energy savings.[1]

      - Electronic Air Cleaner with UV-C light: An electronic air cleaner (EAC) is a device that uses an electric charge to remove impurities, either solid particles or liquid droplets, from the air and uses UV-C light to inactivate pathogens collected. The electronic air cleaner functions by applying energy only to the particulate matter to be collected, without significantly

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impeding the flow of air[18]. EAC with UV-C provides air filtration as well as disinfection. EAC technology has been used effectively for years in commercial and residential buildings. EAC with UV-C as a retrofit solution in an existing HVAC system provides minimal pressure drop, energy efficiency and connectivity with BMS system to provide alerts on cleaning.*

- Needlepoint bipolar ionization (NPBI): This technology uses charged particles called ions to clean air by reducing VOC's [19,20]. There are 3rd party test result that measure the efficacy of NPBI to be 99.4% for COVID19 [21,22]. Implementation involves inserting a device in the supply ductwork that generates electrical charged ions that do three things, a) breaks down harmful VOC gases, b) forms hydroxyls that robs bacteria and pathogens of the hydrogen they need to survive, and c) attaches to airborne particles, which in turn makes them larger and increases the chance of the particle being trapped by air filters. As to the effectiveness of bipolar ionization technology, there are multiple studies dating back to 2005 [23]. ASHRAE comments in their Position Document on Filtration and Air Cleaning [24] that precautions should be taken when considering this technology since pin ionizers that use high voltage can produce ozone (O_3) in air [24].*

* Any air-cleaning device that uses electricity during air cleaning process has the potential to generate ozone. In practice, ozone generation is associated with air cleaners that use high-voltage coronas or pin ionizers (e.g., some precipitators or ionizers), UV light of a sufficiently small wavelength (some photocatalytic oxidizers and UV-C air cleaners), and by some plasma air cleaners." [24] To provide some clarity to this position, there are several ways to generate ions, two are corona discharge and plasma. Products that use corona discharge use a filament with a high voltage and are known to generate ozone which is hazardous to humans. Any product that uses corona discharge should not be considered for air cleaning. Plasma generation uses plasma and a low dc current to create ions. The lower the dc voltage, the less potential to create ozone. Products that use 12 vdc or less are considered "ozone-free". As ASHRAE indicated in their Addendum to 62.1, "Air cleaning devices shall be listed and labeled in accordance with UL 2998.[25] UL 2998 is an environmental claim procedure by Underwriter's Laboratories that certifies a product is a "zero ozone emitting" cleaning device.

Summary

As Airports implement recovery strategies, it is important to understand the effects HVAC systems have in mitigating the transmission of COVID-19 through the terminal. Good practices and proper performance of these systems can dramatically impact the various transmission routes. Keeping particles from becoming airborne, controlling air flow, keeping indoor air clean, and constant monitoring for poor air quality are good and effective practices for ensuring a healthy environment inside the terminal. All of these practices can be implemented with HVAC systems that are operating properly and contain appropriate functionality, equipment, and sensors to reduce and mitigate the airborne transmission of COVID-19. The good practices provided in this white paper represent the best industry knowledge at the time of authoring. It is recognized these will evolve as new solutions, technologies, and testing continue.

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