Ventilation and HVAC Recommendations in Relation to COVID-19

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Executive Summary

This paper will review the spread of aerosols in occupied buildings in two categories (1) unconditioned spaces with cooling by ventilation and air movement and (2) conditioned buildings that are regularly occupied. Recommendations provided throughout are those that should be made above and beyond the standard recommendations of the WHO and CDC to reduce transmission of the virus by means of social distancing, personal protective equipment (PPE) and good hygiene practices. This paper provides the following recommendations regarding engineering controls for these spaces:

Unconditioned Spaces

- Ensure that ventilation systems are in proper working order, and provide (at minimum) ventilation levels at least at ASHRAE 62 rates. Where practical, increase ventilation rates to maximum levels achievable. Do not disable ventilation systems as a means to stop the spread of COVID-19. Unconditioned spaces can cause thermal stress to people that may be directly life threatening and may also lower resistance to infection.
- Provide airflow directed from overhead in lieu of airflow directed horizontally. Overhead airflow should be at a high volume, low velocity to minimize distribution of droplets.
- If horizontal airflow is unavoidable, ensure that airflow does not direct air past one worker at other workers. The horizontal airflow would be directed towards an exhaust location and exhaust would ideally be located at low elevations on sidewalls.

Conditioned Spaces

- Determine the highest space temperature and humidity that the building occupants can tolerate during the current pandemic situation in the summer, and the lowest temperature in the winter.
- Ideal relative humidity range is from 40-60%. However, during the winter this will be difficult. Humidity should only be added to a building with caution to prevent condensation from occurring during the cold weather months.
- Verify that the current BAS (Building Automation System) control sequence is working as intended. If the facility uses a demand control ventilation BAS control sequence that automatically reduces the amount of outside air brought into the building, it is recommended that the demand control ventilation sequence be disabled. If disabling demand control ventilation (DCV) is not an option, reset the target space CO2 level as low as possible.
- Revise the BAS control sequence to give ventilation a priority:
    - Increase ventilation fraction as high as possible.
    - In VAV systems, ensure that terminal air boxes have minimums that are as high as possible. Consider increasing them beyond normal design levels. Increasing supply air temperature may be possible in systems with chilled water coils.
    - Allow ventilation to continue 24/7, even during unoccupied times. This will purge the building during unoccupied hours.

- For chilled water systems, consider lowering Chilled Water Supply Temperature as low as possible to maximize coil capacity.
- Verify that dampers controlling outside air and return air are working properly.
- Ensure exhaust levels in restrooms are at least the minimum required by building code. Increase restroom exhaust to the maximum possible levels with given equipment.

Background

In November 2019, China reported is first case and subsequent outbreak of a novel coronavirus called SARS-CoV-2 that causes the disease COVID-19. On February 16, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a Public Health Emergency of International Concern (PHEIC) and then later on March 12, proclaimed it a pandemic. Multiple observational studies and modeling of COVID-19 indicate transmission of the virus is made through the air via aerosols. According to the WHO, "The COVID-19 virus spreads primarily through droplets or saliva or discharge from the nose when an infected person coughs or sneezes…" Talking and breathing can also release droplets and particles. Droplets generally fall to the ground or other surfaces in about 3ft, while particles (aka aerosols) behave more like a gas and can travel through the air for longer distances, where they can transmit to people and also settle on surfaces.[2]

There is great concern about the possibility of transmission through the air of various pathogens, especially SARS-CoV-2, among staff and administration in healthcare facilities, workers in office environments, staff and patrons in retail settings, workers in manufacturing, residents in private and public facilities, and the general public in outdoor settings and in public transportation.[1] With infectious diseases transmitted through aerosols, HVAC systems can have a major effect on the transmission from the primary host to secondary hosts.[3] Decreasing exposure of secondary hosts is an important step in curtailing the spread of infectious diseases.[3] Ventilation and filtration provided by heating, ventilation and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air.[1] The use of engineering controls involve isolating employees from work-related hazards.[7] These types of controls reduce exposure to hazards without relying on worker behavior.[7]

Unconditioned Spaces

Many buildings utilize natural ventilation. In a full or hybrid system, natural ventilation is the use of operable windows or other openings in in the building envelope for cooling. While airflow in naturally ventilated spaces is more unpredictable, ventilation strategies can be used to reduce the risk from infectious aerosols. Generally speaking, designs that achieve higher ventilation rates will reduce risk.[3] However, such buildings will be more affected by local outdoor air quality, including the level of allergens and pollutants within the outdoor air, varying temperature and humidity conditions, and flying insects.[3]

In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus.[1] Unconditioned spaces can cause thermal stress to people that may be directly life threatening and may also lower resistance to infection.[1] Both building and personalized ventilation should be increased to ensure workers comfort and decrease the transmission of aerosols. Personalized ventilation systems that provide local exhaust source control and/or supply 100% outdoor, highly filtered, or UV-disinfected air directly to the occupant's breathing zone may offer protection against exposure to contaminated air. Personalized ventilation may be effective against aerosols that travel both long distances as well as short ranges.[3]

ASHRAE provides the following recommendations for modifications to building HVAC system operation that should be considered for naturally ventilated, unconditioned spaces[2],[3]:

- Increase outdoor air ventilation, minimizing or eliminating recirculation
  - Disable demand-controlled ventilation (DCV).
  - Open out-door air dampers to 100% as indoor and outdoor conditions permit.
- Improve central air and other HVAC filtration to MERV-13 (ASHRAE 2017b) or the highest level achievable on any recirculated air.
- Keep systems running longer hours (24/7 if possible).
- Consider adding portable room air cleaners with HEPA or high-MERV filters with due consideration to the clean air delivery rate.
- Consider adding portable UVGI (ultraviolet germicidal irradiation) devices in connection to in-room fans in high-density spaces such as waiting rooms and break rooms.

Given the transmission statement above from the WHO, point of use fans blowing air horizontally creates a potential risk for transmission. Workers become both the potential source of the contamination and the object for protective measures. The following are recommendations in relation to the use of fans in unconditioned spaces:

- Pointing fans directly at workers has the potential to increase virus transmission. Airflow directed from overhead is recommended over airflow directed horizontally.
- Overhead airflow should be at a high volume, low velocity to minimize distribution of droplets.
- If horizontal airflow is unavoidable, ensure that airflow does not direct air past one worker at other workers.
- Preferably, the horizontal airflow would be directed towards an exhaust location and exhaust would ideally be located at low elevations on sidewalls.

Conditioned Occupied Buildings

Conditioned spaces have multiple areas to address when exploring engineering controls to reduce transmission of infectious aerosols. The design and operation of heating, ventilating, and air-conditioning (HVAC) systems, including air filtration, and exhaust ventilation, should all be reviewed to decrease the risk of infection transmission. An HVAC system's impact will depend on source location, strength of the source, distribution of the released aerosol, droplet size, air distribution, temperature, relative humidity, and filtration.[3]

The first step in evaluating an HVAC system to make improvements to reduce aerosol transmission is to identify the acceptable space comfort conditions during an epidemic. This is likely an increased temperature set point above the current space controls to allow for increased outside air (OA). Determine the highest space temperature and humidity that the building occupants can tolerate during the current pandemic situation in the summer, and the lowest temperature in the winter. Look at the potential to increase cooling set points to 78 F and 60% relative humidity[4] for the warm weather months.

Building Automation System (BAS) can be used to dynamically respond to the space conditions and increase ventilation air in the system. This means the BAS will prioritize ventilation control over other optimization strategies.[4] Verify that the current BAS control sequence is working as intended. Then, utilize the BAS to have outside air dampers and return air dampers respond to the space[4] conditions so that the maximum amount of ventilation is provided for given conditions. Disable or modify demand control ventilation (DCV) control sequences as applicable to allow for increase in OA. If disabling DCV is not an option, reset the target space CO2 level as low as possible. Revise the BAS control sequence to give ventilation a priority as follows:

- Increase ventilation fraction as high as possible until the space conditions above are met. In variable air volume (VAV) systems, it may be possible to raise supply air (SA) temperature if space temperature and humidity can be increased
- In VAV systems, ensure that terminal air boxes have minimums that will allow for adequate airflow under all conditions. Consider increasing them beyond normal design levels.
- Allow ventilation to continue 24/7, even during unoccupied times. This will purge the building during unoccupied hours.

Ventilation with effective airflow patterns is a primary infectious disease control strategy through dilution of room air around a source and removal of infectious agents.[3] However, ventilation is not capable of addressing all aspects of infection control.[3] It remains unclear by how much infectious particle loads must be reduced to achieve measurable reduction in disease transmissions. [3] When reviewing building ventilation systems, first you should ensure that ventilation systems are in proper working order, including dampers controlling outside air and return air are working properly. At a minimum, all facilities of all types should follow the latest published standards and guidelines of ANSI/ASHRAE Standards 62.1 and 62.2.3 Going beyond these standards is highly recommended. Additionally, specific to restrooms, ensure exhaust levels are adequate and increase to the maximum possible exhaust with given equipment.

Scientific literature generally reflects the most unfavorable survival for microorganisms when relative humidity is between 40% and 60%.[3] However, during the winter this range is difficult to achieve. Humidity should only be added to a building with caution to prevent condensation from occurring during the cold weather months.

In general, systems should increase OA as much as possible through the use of the BAS controls and ventilation. However, going from 20 to 90% OA requires twice the cooling capacity and three times the water-pressure drop (for hydronic systems) for the pump to overcome.[4] For chilled water systems, consider lowering chilled water supply temperature as low as possible to maximize coil capacity. Dehumidification strategies may also need to be considered if OA is increased in areas with high outside humidity.

Direct-expansion (DX) coils can be more challenging than chilled water systems when trying to increase OA quantities. DX coils will have latent load limitations that may restrict how much humid outside air can be brought into the system. Carefully evaluate coil capabilities as you increase OA.

The use of highly efficient particle filtration in centralized HVAC systems reduces the airborne load of infectious particles.[3] Where possible, MERV 13 filters (or better) should be used in central AC units. Check filters to ensure they are within service life and appropriately installed.[6] The MERV 13 filter is better at removing 0.1-micron-sized particulate than the MERV 8. However, higher efficiency filters will result in increased static pressure loss, which will reduce the total supply airflow available. Thus, higher static pressure will result in increased fan energy consumption and low supply cfm. The increase in static pressure may need to be addressed by a Commissioning Agency.

When appropriately selected and deployed, single-space high-efficiency filtration units (either ceiling mounted or portable) can be highly effective in reducing/lowering concentrations of infectious aerosols in a single space.[3] This is particularly true when HEPA filters are employed. However, it is important to note, filtration will not eliminate all risk of transmission.

An additional option for air cleaning is the use of UVGI in a system. UVGI is an air cleaning technology that is sometimes used in buildings. UVGI uses low-wavelength ultraviolet light (UV-C light) to destroy viruses. UVGI has been shown to be effective in disinfecting surfaces and air from bacteria and viruses such as infuenza.[5] The safety of UV-C is well known. It does not penetrate deeply into human tissue, but it can penetrate the very outer surfaces of the eyes and skin, with the eyes being most susceptible to damage. The entire UV spectrum can kill or inactivate microorganisms, but UV-C energy (in wavelengths from 200 to 280 nm) provides the most germicidal effect, with 265 nm being the optimum wavelength.[3] If used, shielding is needed to prevent direct exposure to the eyes. UVGI may be able to reduce exposures to airborne COVID-19.

Similar to the list above for unconditioned spaces, ASHRAE provides the following recommendations for modifications to building HVAC system operation that should be considered for condition spaces[2],[3]:

- Increase outdoor air ventilation, minimizing or eliminating recirculation
  - Disable demand-controlled ventilation (DCV)
  - Open out-door air dampers to 100% as indoor and outdoor conditions permit.
- Improve central air and other HVAC filtration to MERV-13 (ASHRAE 2017b) or highest compatible filtration possible on any recirculated air
- Keep systems running longer hours (24/7 if possible).
- Consider adding portable room air cleaners with HEPA or high-MERV filters with due consideration to the clean air delivery rate.
- Consider adding duct- or air-handling-unit-mounted, upper room, and/or portable UVGI (ultraviolet germicidal irradiation) devices in connection to in-room fans in high-density spaces such as waiting rooms and break rooms.
- Maintain temperature and humidity as applicable to the infectious aerosol of concern.
- Bypass energy recovery ventilation systems that leak potentially contaminated exhaust air back into the outdoor air supply.

Conclusion

Changes to building operations, including the operation of heating, ventilating, and air- conditioning systems, can reduce airborne exposures.[1] Ventilation, filtration, and air distribution systems and disinfection technologies have the potential to limit airborne pathogen transmission through the air and thus break the chain of infection.[3]
Here are a few key points to takeaway:

- Increase ventilation rates as high as possible with air velocities as low as possible
- Avoid air movement between employees: contain, ventilate, and disinfect
- Consider workstation and work flow layout changes
- Get expert help
    - Commissioning Agents
    - Mechanical Engineers
    - Professional HVAC contractors
    - CIRAS staff

Like all hazards, risk can be reduced but not eliminated.[2] There are limitations of HVAC systems and our current state of knowledge about the virus and its spread.2 Business operation decisions should be based on both the level of disease transmission in the community and your readiness to protect the safety and health of your employees and customers.[6]

References

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