HVAC STRATEGIES FOR MITIGATION OF AIRBORNE TRANSMISSION OF COVID-19 AND OTHER VIRUSES

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While the COVID-19 pandemic is leading to unprecedented changes in many aspects of our lives, at this time IMEG does not believe it will cause major changes to the current industry standard HVAC design philosophies in healthcare or other markets. However, clients will have many questions as they move forward with design plans for construction or renovation of facilities. The following discussion on HVAC design components is meant to provide a better understanding of current HVAC solutions and their effect on viruses, energy use, and maintenance.

Outside Air/IAQ

The effectiveness of increased outdoor air ventilation beyond code requirements is dependent on the virus transmission. IMEG does not believe increasing outside air rates will mitigate droplet transmission of COVID-19. However, increased outdoor air ventilation of central air handlers beyond ventilation code minimum values can improve dilution and reduce recirculation of aerosolized viruses.

Increased outdoor air ventilation and disabled demand control ventilation strategies will increase energy consumption, however, and should be limited to periods of high risk or concern. In addition, facilities should ensure that restrooms are fully exhausted and not recirculated. (During warmer months facilities may not be able to achieve 100% outside air without negatively impacting thermal comfort and humidity levels in the space.)

Summary of increased outside air rates beyond code:

- Effective dilution of aerosolized viruses
- Not effective with surface-borne droplets or viruses
- Increased energy consumption from mechanical heating and cooling and fan use

Filtration

It's important to note that filters do not kill viruses; they simply attempt to stop the transmission of particles passing through the system. The ability or inability of filters to capture the virus is dependent on the ability of the system to capture particles from the room and return them to the air handling unit (AHU).

Common HVAC system design with ceiling supply and ceiling return has insufficient spot velocity to capture the droplet types of particles (the primary transmission of COVID-19) that travel a relatively short distance

How viruses are transmitted through the air

Aerosol transmission occurs when a liquid or solid (virus) is suspended in air or another gas. An aerosolized particle can remain suspended in the air for several hours depending on temperature and humidity.

Droplet transmission occurs when a liquid or solid (virus) is airborne for a few seconds after someone sneezes or coughs. Droplets only travel a short distance before falling to space surfaces. (Surface cleaning and sterilization is more effective than most HVAC strategies for combating droplet-borne viruses.)

SARS-CoV-2 transmission: COVID-19 is predominantly spread via droplet transmission and can survive on surfaces for several hours (hence the importance of handwashing after touching a surface in public places). The virus has the potential to be transmitted as an aerosol, but current evidence indicates this is under very limited conditions that can be managed. (Aerosolization of the coronavirus has been shown to occur during the intubation of an infected patient, which is why the CDC recommends the intubation of an infected patient be done in a negative-pressure airborne infection isolation room.)

in the air or reside on surfaces. Directionalized airflow patterns, such as laminar ceiling supply and low returns, may offer a slightly better opportunity to capture droplet particles but are more effective at capturing aerosolized particles such as measles or tuberculosis. This is why those patients must be treated in negative-pressure isolation rooms.

Filters are rated based on their ability to stop various-sized particles. Viruses can come in a wide variety of sizes ranging from over 6 micron down to 0.01 micron – and only certain types of filters can stop the very small particle sizes. The Minimum Efficiency Reporting Value (MERV) scale measures the effectiveness of air filters relative to particle size, with ratings from MERV 1 to 20. (See table below.)

MERV 17 and higher are called High Efficiency Particulate Air (HEPA) filters. Only true HEPA filters are rated > 99.9% effective at removing the small particles. Many products advertise and promote the use of HEPA filters, but not all of them have been tested and applied with a MERV 17 or higher rating. Also, HEPA filters are not applicable to all equipment or projects, as some equipment cannot accommodate HEPA filters due to pressure drop and the need for additional fan horsepower. The product should be reviewed before applying to your system.

It is not uncommon for an HVAC system to utilize MERV 8 filters – which ASHRAE suggests being upgraded to MERV 13 or higher if possible. The difference in pressure drop between MERV 8 and MERV 13 filters can be low and the minimal effect it may have on system

MERV Rating	Air Filter will trap Air Particles size .03 to 1.0 microns	Air Filter will trap Air Particles size 1.0 to 3.0 microns	Air Filter will trap Air Particles size 3 to 10 microns	Filter Type ~ Removes These Particles
MERV 1	< 20%	< 20%	< 20%	Fiberglass & Aluminum Mesh
MERV 2	< 20%	< 20%	< 20%	~
MERV 3	< 20%	< 20%	< 20%	Pollen, Dust Mites, Spray Paint,
MERV 4	< 20%	< 20%	< 20%	Carpet Fibres
MERV 5	< 20%	< 20%	20% - 34%	Cheap Disposable Filters
MERV 6	< 20%	< 20%	35% - 49%	~
MERV 7	< 20%	< 20%	50% - 69%	Mold Spores, Cooking Dusts,
MERV 8	< 20%	< 20%	70% - 85%	Hair Spray, Furniture Polish
MERV 9	< 20%	Less than 50%	85% or Better	Better Home Box Filters
MERV10	< 20%	50% to 64%	85% or Better	~
MERV 11	< 20%	65% - 79%	85% or Better	Lead Dust, Flour, Auto
MERV 12	< 20%	80% - 90%	90% or Better	Fumes,Welding Fumes
MERV 13	Less than 75%	90% or Better	90% or Better	Superior Commercial Filters
MERV 14	75% - 84%	90% or Better	90% or Better	~
MERV 15	85% - 94%	95% or Better	90% or Better	Bacteria, Smoke, Sneezes
MERV 16	95% or Better	95% or Better	90% or Better	
MERV 17	99.97%	99% or Better	99% or Better	HEPA & ULPA
MERV 18	99.997%	99% or Better	99% or Better	~
MERV 19	99.9997%	99% or Better	99% or Better	Viruses, Carbon Dust, <.30 pm
MERV 20	99.99997%	99% or Better	99% or Better	
Illustration Provided by LakeAir / www.lakeair.com				

airflow reduction is usually an acceptable tradeoff for the improved filtration. ASHRAE also suggests room-level portable cleaners with HEPA or high MERV filters may be considered to clean the air within a space.

Summary of increased filtration at the AHU:

- Does not kill or sterilize particles
- Effective at capturing aerosolized virus particles depending on particle size and MERV rating
- Increased pressure-drop and energy consumption

AHU/Coil-level UVGI

Adding special coil-level ultraviolet germicidal irradiation (UVGI) to HVAC systems can be very effective in the sterilization of aerosolized viruses, but like filters their effectiveness is dependent on the HVAC system's ability to remove the particles from the room and pull them back to the AHU.

Fresh-Aire UV

However, adding AHU-level UVGI offers no real protection from the droplet type of viruses such as COVID-19. Like the filter discussion above, this is because normal HVAC system design with ceiling supply and ceiling return has insufficient spot velocity to capture the droplets.

Additionally, not all UVGI lights in air handling systems are intended for full sterilization. The most common UVGI intensity in an AHU is designed and sized only for coil/drain pan sterilization to reduce microbial growth. This intensity of UVGI light is typically not intended nor can it be modified to sterilize moving air. In such situations the UVGI will need to be replaced with a unit providing the needed intensity.

Summary of adding UVGI to AHUs with the proper intensity:

- Proven effective at killing or sterilizing viruses
- Proven effective at killing molds, bacteria and biofilms
- Effective when particles can be drawn through the HVAC system to the AHU (aerosolized viruses)
- Normally does not change AHU arrangement and layout
- Not effective with droplet/surface-borne viruses
- Increased energy consumption
- Not effective at the space level when using a 100% dedicated outside air system (DOAS)

Room-level UVGI

Room-level UVGI come in permanent and portable types and can kill or sterilize virus particles that are moved by air currents from the protected area to the irradiated area. Permanent UVGI lamps are installed in the room at the ceiling level and should be guarded to protect the occupants from direct exposure to the UVC light. Portable UVGI can operate at a much higher intensity level and can directly sterilize all exposed surfaces.

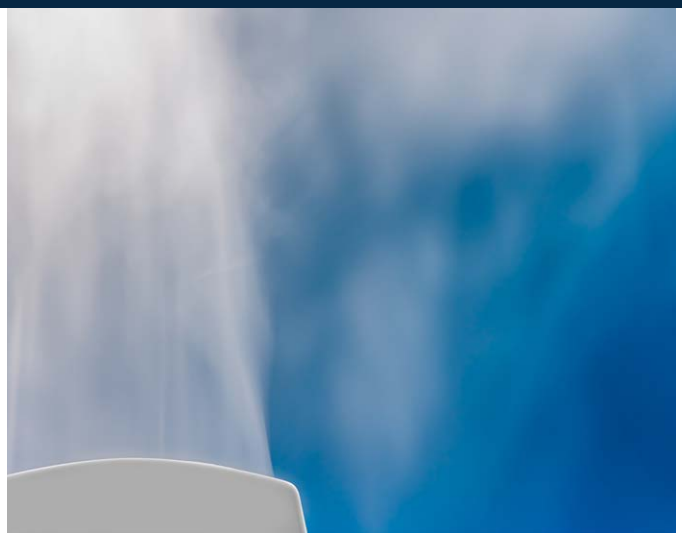
Since direct exposure to UVC can cause eye and skin irritation and burns, portable UVGI should be operated when a room is unoccupied. Direct exposure to UVC also can degrade organic materials and many plastics. The basic approach is to use UV-resistant materials whenever possible and shield materials that will degrade significantly.

Summary of room-level UVGI:

- Effective at killing or sterilizing viruses, including surface-borne
- Effective at killing molds, bacteria and biofilms
- Increased energy consumption
- Direct exposure causes skin and eye irritation
- Direct exposure causes material degradation

Humidification

Higher humidity levels increase the density of the air, thereby increasing the drag force



on a particle and allowing gravity to take over. Studies show that spaces with a relative humidity (RH) between 40% and 60% can cut the airborne travel distance of viral droplets and reduce the risk of infections, but not all facilities or locations will have the capacity to achieve these humidity levels at all conditions. Additionally, the increased humidity could affect the building envelope and increase energy and maintenance costs to create water vapor. Many envelope vapor barriers and windows are not suitable for 40% RH and condensation and frosting can occur in cold weather (causing damage to the envelope).

Summary of adding humidifier to AHU or space:

- Effective at reducing the momentum of particles and transmission distances
- Reduces static electricity in typically dry environments
- Can be added directly in the space
- Increased energy consumption to generate water vapor
- Increased water usage
- Concern for condensation and frosting on or in the envelope during cold weather

Needle Point Ionization/Plasma

NPI (aka plasma) claims to kill many viruses, mold, bacteria, and fungi in the AHU and in the occupied space. The process creates positive and negative ions that attract each other and combine with small particles in a "snowball effect" that makes the particles larger – thus increasing the effectiveness of the existing filtration systems. It is also claimed that ionization creates OH (hydroxyl radicals), which draw hydrogen atoms out of the pathogen and kill or inactivate it.

There is some literature showing NPI's effectiveness at reducing pathogen counts in lab conditions. NPI also can break down some VOCs into their constituent elements (mostly hydrogen, carbon, oxygen, and nitrogen), which then combine into non-VOCs (H2O, O2, N2, etc.), thereby removing VOCs and odors.

IMEG has had recent client requests for installation of NPI on their projects. However, there is insufficient experience to provide a strong recommendation for or against the strategy.

NPI summary:

- Manufacturer provides documentation claiming effectiveness at killing viruses
- No added pressure drop in AHUs
- Does not change AHU arrangement and layout
- Increased energy consumption to power the process

Future considerations

IMEG will continue to monitor the COVID-19 pandemic and any future considerations it may have on HVAC strategies and best practices moving forward. Clients are encouraged to consider us as an extension of their facility staff for assistance in ensuring the best solutions for protecting against airborne virus transmission.

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Related reading:

COVID-19: What our healthcare clients are doing, and what we recommend for infection control, by Mike Zorich, IMEG National Director of Healthcare

The new coronavirus can likely remain airborne for some time. That doesn't mean we are doomed, by Sharon Begley, STAT News

Guidance for Building Operations During the COVID-19 Pandemic, by Lawrence J. Schoen, P.E., Fellow/Life Member ASHRAE