Managing Buildings Post Covid-19

A New Paradigm in Building Management is Imposing Itself

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This note reviews available technologies, products and guidelines related to safely managing HVAC systems in commercial buildings in light of Covid-19. It should be noted that in this unfolding crisis, there are conflicting opinions about almost every Covid-19 counter measure out there, including how to best manage buildings. Part of it is because our knowledge of Covid-19 is still evolving; any conclusions drawn to date will have to be revisited as our understanding of Covid-19 evolves.

This note is only meant to serve as a guide and does not replace the need to conduct proper engineering analysis of the most appropriate solution for each building. A more detailed review of Covid-19 measures is available upon request (mkamel@melrok.com).

Buildings are designed to protect us from the elements and offer us a safe and comfortable environment to work and study in; however, their enclosed environment can favor the spread of viruses within the building. Conventional building management controls are all focused on managing buildings based on occupant comfort (temperature and in some cases humidity). While air quality has always been a design consideration in buildings, it has mainly been from the perspective of removing air pollutants, dust particles, pollen, and bacteria from the air. In the post Covid-19 era, bio-safety from airborne infectious diseases is starting to take precedent over comfort-related issues. This presents a challenge to building managers and to the heating, ventilation and air conditioning (HVAC) systems used to condition the air in commercial buildings.

It may be that the toughest challenge in protecting buildings against Covid-19, and any other future airborne virus, is the logistics of changing the control logic of their building management system and the controllers used to manage individual HVAC units in a building - from the large rooftop units to smaller units above the ceilings of hallways and rooms.

Using conventional approaches to implement these changes can be prohibitively expensive and time consuming. Reverting the changes when the pandemic is over will be equally expensive unless new approaches are implemented such as cloud-managed HVAC set points. Cloud managed buildings are not science fiction, most buildings can be transformed to cloud-managed buildings with insignificant capital investments and with less labor cost than it takes to make the required program changes needed to comply with recommended guidelines to fight Covid-19.

A new paradigm in building controls is needed

The systems that manage the conditioning of air in buildings are programed to achieve a comfortable environment inside each room. Typically they are guided by temperature alone, with the amount of air supplied to each room being a function of how much cooling or heating the room needs. If the room is in its comfort zone (in terms of temperature), then ventilation to the room decreases and so does the number of times the air is changed in the room. With today's emerging concerns on the bio-safety of the air in buildings, the number of required air changes in high-traffic rooms needs to be practically independent of the room's environment. Frequent air changes are needed to mitigate the spread of infectious diseases even if the conditioned space is within its desired environmental comfort zone. Spaces with high occupant traffic (or regular rotation of occupants) will need frequent air changes even if the actual occupant count is not high.

Another handicap of existing control sequences is that the amount of outside air supplied to a commercial building is typically a function of the ambient air conditions. While a minimum percentage of outside air may be required by code, the amount of outside air supplied to the building is minimized when ambient temperatures increase beyond a threshold (typically a few degrees cooler than the desired temperature in the building).

Covid19-related recommendations of increasing ventilation rates and the amount of outside air supplied to the building at all times can only be met by changing the set points and control logic of dozens, and potentially hundreds, of control devices in a building.

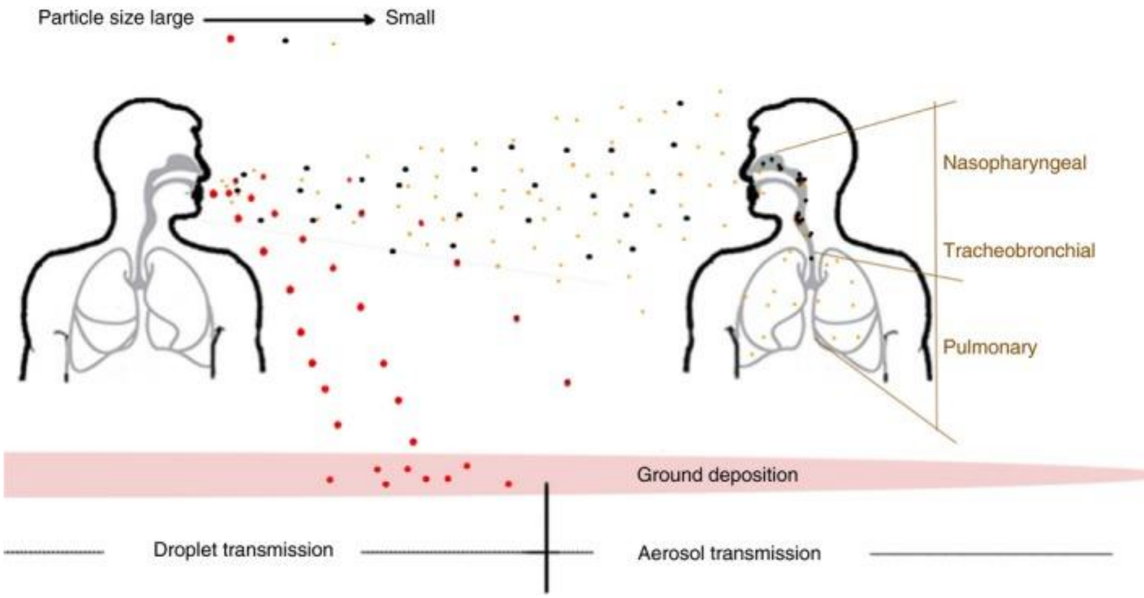
Summary Check List

A list of recommended measures is provided here, with justification for some of the measures given further below. A more detailed review of Covid-19 measures is available upon request.

- ✓ Ensure the building's HVAC systems and controls are operating properly
- ✓ Survey zones and spaces within buildings and Identify those that can be disabled
- ✓ Make necessary changes to the BAS's sequence of operations
  - Maintain a minimum number of air changes in occupied spaces
  - Maximize the use of outside air in ventilation
  - Review and relax the acceptable temperature set points
  - Maintain indoor relative humidity above 40%
  - Monitor outdoor ozone levels, manage as needed
- ✓ Consider the use of upper room UV solutions in high occupancy / traffic spaces
- ✓ Consider the use of HEPA space air filters in high occupancy / traffic spaces
- ✓ If recycling the air, upgrade HVAC system filters to MERV 13 or higher if possible
- ✓ If recycling the air, investigate other technologies such as in-duct UV
- ✓ Add new sensors as needed (e.g. relative humidity and ozone)
- ✓ Engage occupants
- ✓ Keep tabs on the CDC's and ASHRAE's related guidelines

Understanding the Threat: Airborne Particles

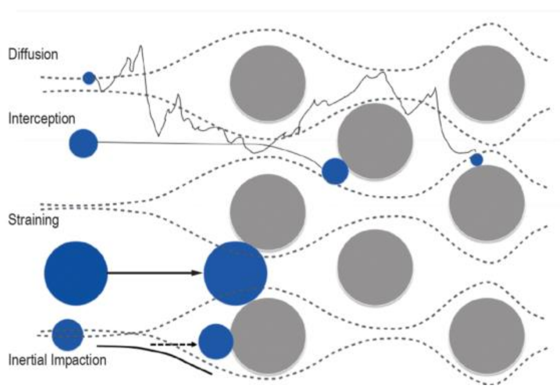
Viruses can be transmitted via surfaces and / or airborne particles. The jury is still out as to how easily Covid-19 can be transmitted via surfaces; the CDC recently changed its position on that matter. However, one needs to err on the side of caution, hence the use of hand sanitizers, surface disinfectants, etc. The harder challenge is posed by the airborne transmission of viruses. Most prominent risks are from the coughing or sneezing by infected people, both of which disperse tiny particulates in the air that can carry the virus and travel long distances. Such particles can linger for up to 8 hours in still air and contaminate future occupants. The risk also exists that they may travel through the air duct and be re-circulated across the entire building.



Coughing or sneezing ejects airborne particulates some of which can travel long distances. Source of Illustration: Pan M, Lednicky JA, Wu CY. Collection, particle sizing and detection of airborne viruses. J Appl Microbiol. 2019;127(6):1596 - 1611. doi:10.1111/jam.14278

Keeping the Air we Breath Safe

With the main challenge identified – that of protecting against airborne particles – what options are available to keep the building's air safe. Conceptually, we can 1) Filter the air in buildings, 2) Sterilize the air, and / or 3) Constantly supply fresh air to buildings.



Mechanical capturing of particles in air streams. Source: *Submicron and Nanoparticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials*, J.L. Perry et al. Marshall Space Flight Center, Huntsville, Alabama. NASA/TM—2016–218224

Filtering consists of removing particles from the air. All buildings are equipped with fiber-based filters designed to remove pollutants and particles from the air before it circulates (back) into the building. Fiber-based filters are rated based on their efficiency in removing particles of different sizes, with some filters able to remove particles that are more than 1,000 times thinner than human hair. It may be possible to replace a building's existing filters with higher quality filter (MERV 13 or higher) to remove even smaller particles. NASA researchers have demonstrated[1] that fiber-based filters can remove particles smaller than the size of the corona virus. However, the efficiency of fiber filters in removing virus-sized particles is not reported in the related product literature; the standard rating system for filters is based on particle sizes 3 to 8 times larger than the corona virus.

Filters can also be based on electrical (ionization) or chemical activation to remove particles from the air stream. The effectiveness of these filters against viruses has not been proven. Furthermore, the use of ionization filters is not advised due to their potentially dangerous side effects (ozone generation).

Sterilizing consists of effectively killing or deactivating organisms while they are still in the air, or in some cases after they've been removed. Sterilizing techniques include the use of ultra violet light to damage the RNA/DNA structure of viruses, or the membranes of bacteria and other organisms. These techniques have been used to minimize the spread of diseases in hospital rooms[2]. UV sterilization is being proposed as a solution to clean the air while it is passing through the air ducts in buildings. Caution (and engineering) must be exercised when considering in-duct UV sterilization products as a Covid-19 counter measure: the characteristics of relatively still air in a room are different than those of rapidly flowing air in a duct. While the physics of UV disinfection works, vendors' claims of *on-the-fly* disinfection of viruses are often non-substantiated by experiments and product specifications. When considering UV-based solutions, the intensity, spectral frequency and illumination profile of the light source become critical factors. UV light can compliment the use of air filters, when aimed at the filter to destroy any captured virus particles; more experiments are needed to quantify this approach.

Supplying Fresh Air consists of using the building's HVAC systems to constantly exhaust the building's air to the outside, and continuously intake fresh air from vents typically located on the roof. The risks of having contaminated open air some 20 feet or more above the ground are practically negligible. Nature is a great filter and our best friend in fighting viruses. The Sun's radiations can damage many microorganisms within hours, and even a gentle breeze is enough to disperse clusters of particles into negligible concentrations. While supplying fresh air seems to be a good solution, outdoor air needs to be conditioned (heated or cooled) before entering the building, an effort that is energy intensive and taxing on the HVAC systems – and may not be within the capacity of some HVAC systems.

What's the fastest and safest thing to do?

There are questions as to the levels of risk from virus-sized airborne particles being able to recirculate in a building's HVAC ducts and cause the spread of infectious diseases in buildings[3]. In tandem, there is also a certain degree of liability for not taking the appropriate measures given the uncertainty surrounding the spread of Covid-19. It has been shown[4] that influenza particles can be exhaled by infected people through regular breathing (even with no coughs or sneezes) and remain suspended in still air for up to 8 hours. Amidst all the uncertainties, there should be common grounds that ventilation of spaces will decrease the risk of infected airborne particles i) spreading to other spaces (whether through connected spaces or HVAC ducts), and *ii) lingering* in the space where they originated (and thus pose a risk to current and future occupants).

The following recommended steps err on the side of caution as a first response while longer-term solutions are being investigated:

Supply Fresh Air. The safest, and probably fastest, measure to implement is to constantly supply fresh air into the building and to ensure that the air inside each room is changed multiple times an hour. While this is the safest method, it is not necessarily the lowest cost method of operation. As the days get hotter, the building's HVAC system will need to work harder to continuously cool hot outside air as it is being flushed into the building. Similarly, on cold days the HVAC system will need to work harder to keep the building warm. Some HVAC systems may not have the capacity to cool a supply of 100% outside air to the entire building. Hence, in tandem with maximizing use of outside air, dynamic management of the ventilation of individual rooms may be needed to stop the ventilation of unoccupied rooms and increase the ventilation of occupied rooms. Roll up garage doors (warehouses), popup skylights, doors to the outside, and windows that open, can all be used to increase supply of fresh air into a building. Relative humidity of the outdoor air can become an issue on dry days. It is recommended that the relative humidity inside buildings not drop below 40% so as not to favor the spread of viruses.

Maintain Proper Ventilation. It is important to ensure proper ventilation of occupied spaces, including the confirmation that the ventilation equipment (fans, dampers) are working properly and that the building management system's control logic is changed to maintain proper ventilation of occupied spaces even if the space temperature set points have been reached. Ventilation is measured in equivalent air changes per hour (ACH), with one ACH supplying a volume of air per hour equal to the volume of the ventilated space. For reference, six ACHs are required to replace ~ 99.7% of the air in a space within an hour.

Ventilation on its own will help dilute any infected air in a room by mixing it with outside air (by code a minimum of outside air is required at all times in large buildings), and by dispersing it throughout all spaces. Conceptually this presents a risk of spreading the infected particles in other parts of the building. Again the jury is still out as to whether this is a risk and what levels of concentration of infected particles in a space are needed to present a danger to its occupants. Therefore to be safe, increased air ventilation must be applied in tandem with one or more measures: improved filtering, air sterilization, or increasing the amount of fresh outside air supplied to the building.

Treat Potential Contamination Before It Spreads. For rooms with high occupancy and / or occupant rotation, such as public areas, auditoriums or conference rooms, in-room air treatment products can be installed to more rapidly treat the air and help protect against local viral concentrations (such as those resulting from coughs and sneezes) before they spread or linger. Such in-room products include upper room Ultra Violet (UV) light beams, which disinfect the air above head level. As the air in the room mixes, air that is in the bottom of the room floats up and also gets disinfected. Portable (or wall mounted) high efficiency space filters that intake air from the room and exhaust it back into the room after filtering, can also be beneficial in removing contaminated airborne particles from the air. If such space air filters are used, the enclosed filter should be replaced often so as they do not become the source of contamination.

Manage the use of spaces. All occupied spaces that witness high-traffic between different occupant groups or that are open to the public, must be managed. For example, meetings and classes may need to be scheduled at least 30 minutes apart to ensure that the air in the room is replaced with clean fresh air before new occupants come in.

Planning for the long haul

Using 100% outside air may not be sustainable in the long run, because of the increased energy costs and the added duty cycle it imposes on heating and cooling systems. If the risk of spreading infected airborne particles through air ducts is confirmed, solutions that allow for the use of recycled air need to be investigated and implemented. Such solutions include upgrading the in-duct air filters to high efficiency filters, and potentially installing air filters at the inlets/outlets of high-traffic rooms to help contain the spread of particles to and from the rooms. In-duct UV sterilization techniques can also be considered provided there is accurate and scientific testing done on the spectral and irradiance profiles of the light source to allow for the proper sizing of these systems. These products can be considered for use at the air handler or at the air inlets/outlets of high-traffic rooms.

Leapfrog into the future: Cloud-Managed HVAC Set Points

To meet the new mode of operation, the control logic of practically every building management system needs to be changed. This imposes a large burden on energy managers, as most of these systems require site visits by trained personnel to effect these changes.

One solution is to leapfrog into the future of building management by changing the control of the dozens of HVAC set points for each building, and thousands of set points for a portfolio of buildings, from manual control of individual equipment to automated and centralized cloud-based control. Automated continuous cloud optimization of building management systems has already been put in practice for energy optimization of buildings using MelRok's Self Driving Building™ platform. While the platform is focused on reducing energy costs, it is proving to be a great asset in the quick and low cost implementation of required changes in the HVAC control logic to accommodate the emerging guidelines. The platform is compatible with existing building management systems and can be rapidly deployed in buildings.

For additional information on the material presented here and on how MelRok can assist in implementing measures to protect against Covid19, please contact the author.

About the Author

Dr. Kamel (mkamel@melrok.com) co-founded MelRok and managed its growth to a recognized leader in energy optimization and real time demand management systems. Dr. Kamel led the development of a cloud-based platform for real time energy analytics, fault detection, control and optimization of building energy management systems. Michel was principal investigator in several projects, including a $2.5M California Energy Commission grant for the demonstration of an automated continuous cloud-based energy optimization platform for buildings. He has authored 7 US patents in energy management and optimization, 2 US patents in aerospace, and 3 international patents in energy. Dr. Kamel presented his work at dozens of national and international conferences, has served on several technology Boards and currently serves on University of California Irvine's Dean of Engineering Leadership Council.

Dr. Kamel has a Ph.D. in Mechanical Engineering from Stanford University, where he investigated UV laser-based diagnostics of combustible air streams. Prior to MelRok, Dr. Kamel founded an aerospace company that designed an air-launched system for the placement of micro satellites in orbit.

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[1] *Submicron and Nanoparticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials*, J.L. Perry et al. Marshall Space Flight Center, Huntsville, Alabama. NASA/TM—2016–218224.

[2] 2019 ASHRAE Handbook – HVAC Applications, Chapter 62, Ultraviolet Air and Surface Treatment (2019).

[3] CoVid-19 White Paper, Taylor Engineering, June 2, 2020

[4] Nikitin, N., Petrova, E., Trifonova, E., & Karpova, O. (2014). Influenza virus aerosols in the air and their infectiousness. Advances in virology, 2014, 859090.