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Review of COVID-19 in Building Science for Building Owners

- ASHRAE and REHVA Guidance

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As Building Science Experts:

- Our role is to advise building owners and operators how to operate their buildings more effectively in order to inhibit any virus or airborne contaminants

ASHRAE Guidance for Building Operations During the COVID-19 Pandemic (Slides 3-10)

- Guidelines available at:
  https://www.ashrae.org/news/ashraejournal/guidance-for-building-operations-during-the-covid-19-pandemic

Note: Hospitals and health care facilities are beyond the scope of this ASHRAE article though many of the same principles apply to them

Research

- The research on COVID-19 is incomplete
- However:
  The virus that causes COVID-19 is SARS-CoV-2 and until more specific research is complete, it is reasonable to make inferences about spread from the SARS-CoV-1outbreak in 2003 because it is genetically similar

WHO (World Health Organization)

- "The COVID-19 virus spreads primarily through droplets of 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 1 m (3 ft), 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

Other Forms of Transmission

- Direct person-to-person contact
- Indirect contact through inanimate objects like doorknobs
- Through the hands to mucous membranes such as those in the nose, mouth and eyes
- Droplets and possibly particles spread between people in close proximity

For these reasons, basic principles of social distancing (1-2 m or 3-6.5 ft), surface cleaning and disinfection, handwashing and other strategies of good hygiene are far more important than anything related to the HVAC system

Non-HVAC Actions or Buildings that Remain Open

- Increase disinfection of frequently touched surfaces
- Install more hand sanitation dispensers, assuming they can be procured
- Supervise or shut down food preparation and warming areas, including the office pantry and coffee station
- Close or post warning signs at water fountains in favor of bottle filling stations and sinks, or even better, encourage employees to bring their water from home

HVAC Actions Are Suggested

- Increase outdoor air ventilation (use caution in highly polluted areas); with a lower population in the building, this increases the effective dilution ventilation per person
- Disable demand-controlled ventilation (DCV)
- Open minimum outdoor air dampers, as high as 100%, thus eliminating recirculation (in the mild weather season, this need not affect thermal comfort or humidity, but clearly becomes more difficult in extreme weather)

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HVAC Actions Suggested (continued)

- Improve central air filtration to a MERV-13 or the highest compatible filter with the filter rack, and seal edges of the filter to limit bypass.
- Keep systems running longer hours, if possible 24/7, to enhance the two actions above
- Consider portable room air cleaners with HEPA filters
- Consider UVGI (ultraviolet germicidal irradiation), protecting occupants from radiation, particularly in high-risk spaces such as waiting rooms, prisons and shelters

Construction Sites

- Much, but not all, construction work has the recommended social distancing; much, but not all, is outdoors or in partially enclosed and therefore well-ventilated buildings; and many, but not all, workers already use personal protective equipment that sometimes includes masks and gloves
- Governments in some locations have mandated closure of construction sites, while in others work proceeds
- Engineers who perform field observations, commissioning or special inspections must consider what work can be postponed, performed remotely, or conducted using photographic documentation, and what personal precautions to take when site visitation is unavoidable

Providing Advice to Building Operators

- If you are called upon to advise building operators, please use the preceding general guidance, and be sure to combine it with knowledge of the specific HVAC system type in a building and the purpose and use of the facility. Like all hazards, risk can be reduced but not eliminated, so be sure to communicate the limitations of the HVAC system and our current state of knowledge about the virus and its spread.

ASHRAE Position Document on Airborne Infectious Diseases

https://www.ashrae.org/file%20library/about/position%20documents/airborne-infectious-diseases.pdf

- This was reaffirmed by Technology Council, February 5, 2020, and outlines different strategies and their application
- ASHRAE does not provide specific requirements for infectious disease control in schools, prisons, shelters, transportation, and other public facilities other than the general ventilation and air quality requirements of Standards 62.1 and 62.2 (ASHRAE 2013b, 2013c). However, the guidance in this position document (PD) does apply to these facilities.

Varying Approaches for Facility Type

- Healthcare facilities obviously have different requirements. Those requirements are not directly addressed in this presentation.

Ventilation and Air Cleaning Strategies

- Because small particles remain airborne for some period of time, the design and operation of HVAC systems that move air can affect disease transmission in several ways, such as by the following:
  - Supplying clean air to susceptible occupants
  - Containing contaminated air and/or exhausting it to the outdoors
  - Diluting the air in a space with cleaner air from outdoors and/or by filtering the air
  - Cleaning the air within the room

The following strategies: dilution ventilation, laminar and other in-room flow regimes, differential room pressurization, personalized ventilation, source capture ventilation, filtration (central or unitary), and ultraviolet germicidal irradiation or UVGI (upper room, in-room, and in the airstream) are discussed on the following slides.

Ventilation

- Directed supply and/or exhaust ventilation, such as non-aspirating diffusers for unidirectional low-velocity airflow, is important in several settings, including operating rooms (FGI 2010; ASHRAE 2008)
- Natural ventilation, such as that provided by user-operable windows, is not covered as a method of infection control by most ventilation standards and guidelines:
  - There are very few studies on natural ventilation for infection control in hospitals. One guideline that does address it recommends that natural ventilation systems should achieve specific ventilation rates that are significantly higher than the ventilation rates required in practice guidelines for mechanical systems (WHO 2009).

Ventilation (continued)

- Room pressure differentials are important for controlling airflow between areas in a building (Siegel et al. 2007; CDC 2005). For example, airborne infection isolation rooms (AIIRs) are kept at negative pressure with respect to the surrounding areas to keep potential infectious agents within the rooms. Some designs for AIIRs incorporate supplemental dilution or exhaust/capture ventilation (CDC 2005).
- Hospital rooms with immune-compromised individuals are kept at positive pressure in protective environments (PEs) to keep potential infectious agents (e.g., Aspergillus sp. or other filamentous fungi) out of the rooms (Siegel et al. 2007; FGI 2010; ASHRAE 2008)

Ventilation (continued)

- Personalized ventilation systems that supply 100% outdoor air, highly filtered, or UV disinfected air directly to the occupant's breathing zone (Cermak et al. 2006; Sekhar et al. 2005) may be protective as shown by CFD analysis (Yang et al. 2013). However, there are no known field studies that justify the efficacy
- The addition of highly efficient particle filtration to central ventilation systems is likely to reduce the airborne load of infectious particles (Azimi and Stephens 2013). This control strategy can reduce the transport of infectious agents within individual areas and from one area to another when these areas share the same central ventilation system (e.g., from patient rooms in hospitals or lobbies in public access buildings to other occupied spaces)

Ventilation/Air Cleaning

There are two UVGI strategies for general application:

1. Installation into air handlers and/or ventilating ducts
2. Irradiation of the upper air zones of occupied spaces with shielding of the lower occupied spaces because UV is harmful to room occupants (Reed 2010). Two strategies used in some but not all health-care occupancies are in-room irradiation of unoccupied spaces and of occupied spaces (e.g., operating suites)

Temperature and Humidity

- Many HVAC systems can control indoor humidity and temperature which can, in turn, influence transmissibility of infectious agents
- Although the weight of evidence at this time suggests that controlling relative humidity (RH) can reduce transmission of certain airborne infectious organisms, including some strains of influenza, the ASHRAE PD refrains from making a universal recommendation

Temperature & RH (continued)

According to Memarzadeh (2011), in a review of 120 papers conducted on the effect of humidity and temperature on the transmission of infectious viruses, numerous researchers suggest that three mechanisms could potentially explain the observed influence of RH on transmission

1) slower evaporation from large droplets influenced by higher humidity that a lower humidity would more rapidly change them into droplet nuclei

2) RH may act at the level of the host. Breathing dry air could cause desiccation of the nasal mucosa, which would in turn render the host more susceptible to respiratory virus infections.

3) RH may act at the level of the virus particle to affect its virulence

ASHRAE Recommendations

- Some infectious diseases are transmitted through inhalation of airborne infectious particles, which can be disseminated through buildings by pathways that include ventilation systems. Airborne infectious disease transmission can be reduced using dilution ventilation; directional ventilation; in-room airflow regimes; room pressure differentials; personalized ventilation; and source capture ventilation, filtration, and UVGI.
- Facility designs should follow the latest practice standards
- Commissioning and maintenance is important
- Infection control strategies should always include a bundle of multiple interventions (not just ventilation)
- More studies and research should be conducted to better characterize particle size distributions of coughed materials which are thought to encompass a broad range of diameters

ASHRAE Position Document on Airborne Infectious Disease

Table 1 Airborne Infectious Disease Engineering Control Strategies: Occupancy Interventions and Their Priority for Application and Research

Strategy	Occupancy Categories Applicable for Consideration*	Application Priority	Research Priority
Dilution ventilation	All	High	Medium
Temperature and humidity	All except 7 and 11	Medium	High
Personalized ventilation	1, 4, 6, 9, 10, 14	Medium	High
Local exhaust	1, 2, 8, 14	Medium	Medium
Central system filtration	All	High	High
Local air filtration	1, 4, 6, 7, 8 10	Medium	High
Upper-room UVGI	1, 2, 3, 5, 6, 8, 9, 14	High	Highest
Duct and air-handler UVGI	1, 2, 3, 4, 5, 6, 8, 9, 14	Medium	Highest
In-room flow regimes	1, 6, 8, 9, 10, 14	High	High
Differential pressurization	1, 2, 7, 8 11, 14	High	High

Note: In practical application, a combination of the individual interventions will be more effective than any single one in isolation.
*Occupancy Categories:

1. Health care (residential and outpatient)
2. Correctional facilities
3. Educational < age 8
4. Educational > age 8
5. Food and beverage
6. Internet café/game rooms
7. Hotel, motel, dormitory
8. Residential shelters
9. Public assembly and waiting
10. Transportation conveyances
11. Residential multifamily
12. Retail
13. Sports
14. Laboratories where infectious diseases vectors are handled

Engineers' Advice to Building Owners

At the building level, engineers may provide support by:

1. Identifying vulnerabilities with air intake, wind direction, shielding, etc.
2. Identifying building systems and safe zones in the general building environment
3. Identifying approaches to interrupting air supply to designated "shelter-in-place" locations in general building environments
4. Identifying cohorting possibilities for pandemic situations so that whole areas of a hospital may be placed under isolation and negative pressure

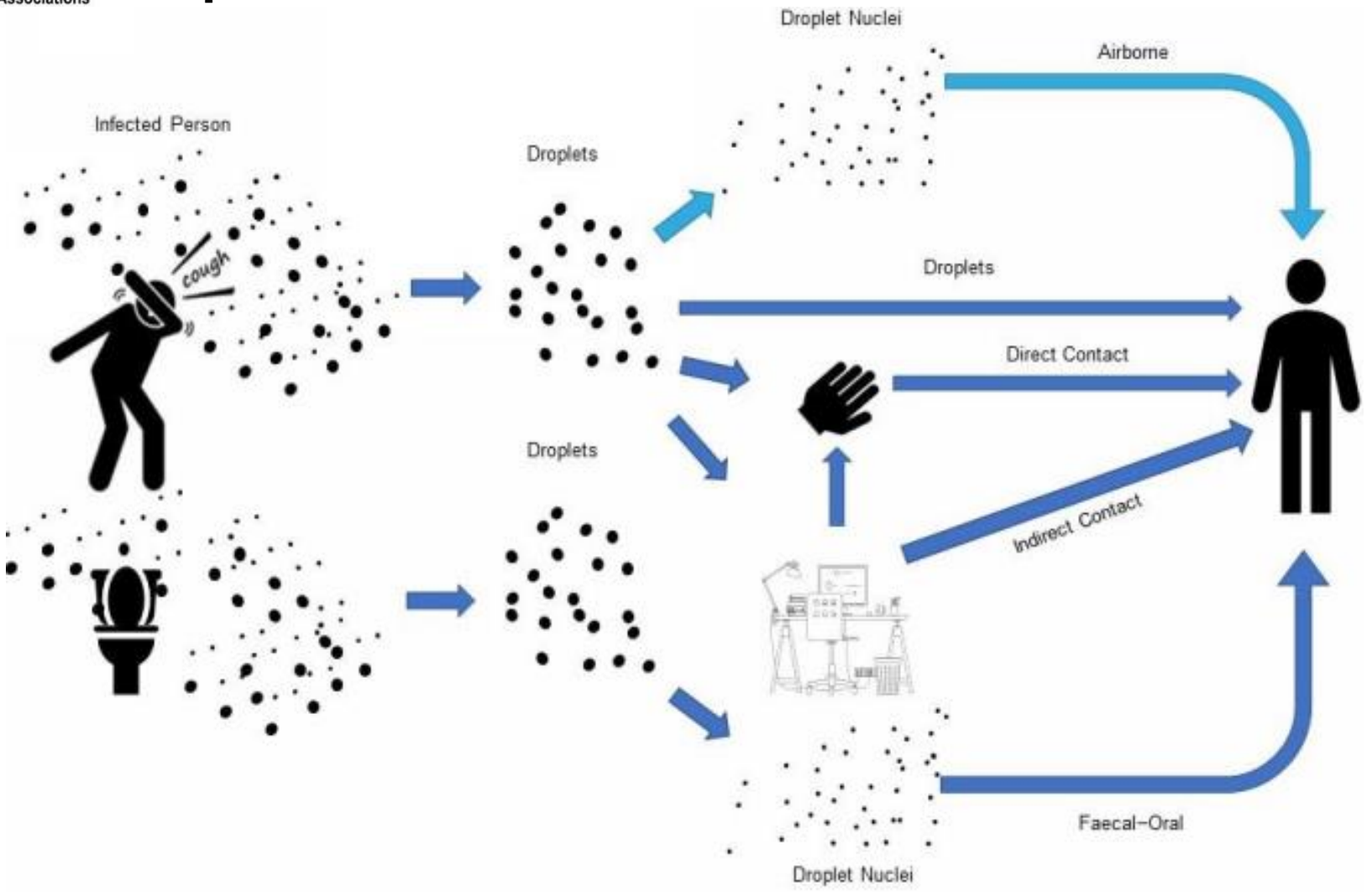
For guidance, see "Airborne Infectious Disease Management Manual: Methods for Temporary Negative Pressure Isolation" (MDH 2013)

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA Published the guidance document:

How to Operate and Use Building Services to Prevent the Spread of COVID-19



WHO reported exposure mechanisms of COVID-19 SARS-CoV-2 droplets (dark blue colour). Light blue colour: airborne mechanism that is known from SARS-CoV-1 and other flu, currently there is no reported evidence specifically for SARS-CoV-2
(figure: courtesy REHVA & Francesco Franchimon).

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REHVA Federation of European Heating, Ventilation and Air Conditioning Associations

Practical Recommendations Ventilation

- Increase air supply and ventilation
  - Extended operation of mechanical ventilation systems (change clock times)
  - Demand control ventilation change CO2 setpoint to lower than 400ppm value
  - Keep ventilation on 24/7 at reduced speed
  - Exhaust ventilation systems of toilets should always be kept on 24/7 and make sure underpressure is created in bathrooms

Natural Ventilation

- Use more window airing
  - Suggest open windows 15 minutes when entering room
  - Do not open windows in toilets with passive stack or mechanical exhaust systems for it can infiltrate into other rooms

Relative Humidity & Temp

- Coronaviruses are resistant to environmental change and although RH >80% and T>30degC may* have minimal effect on the viruses, those temperatures and humidities are not reasonable for buildings.

* More research is needed to confirm

Heat Recovery

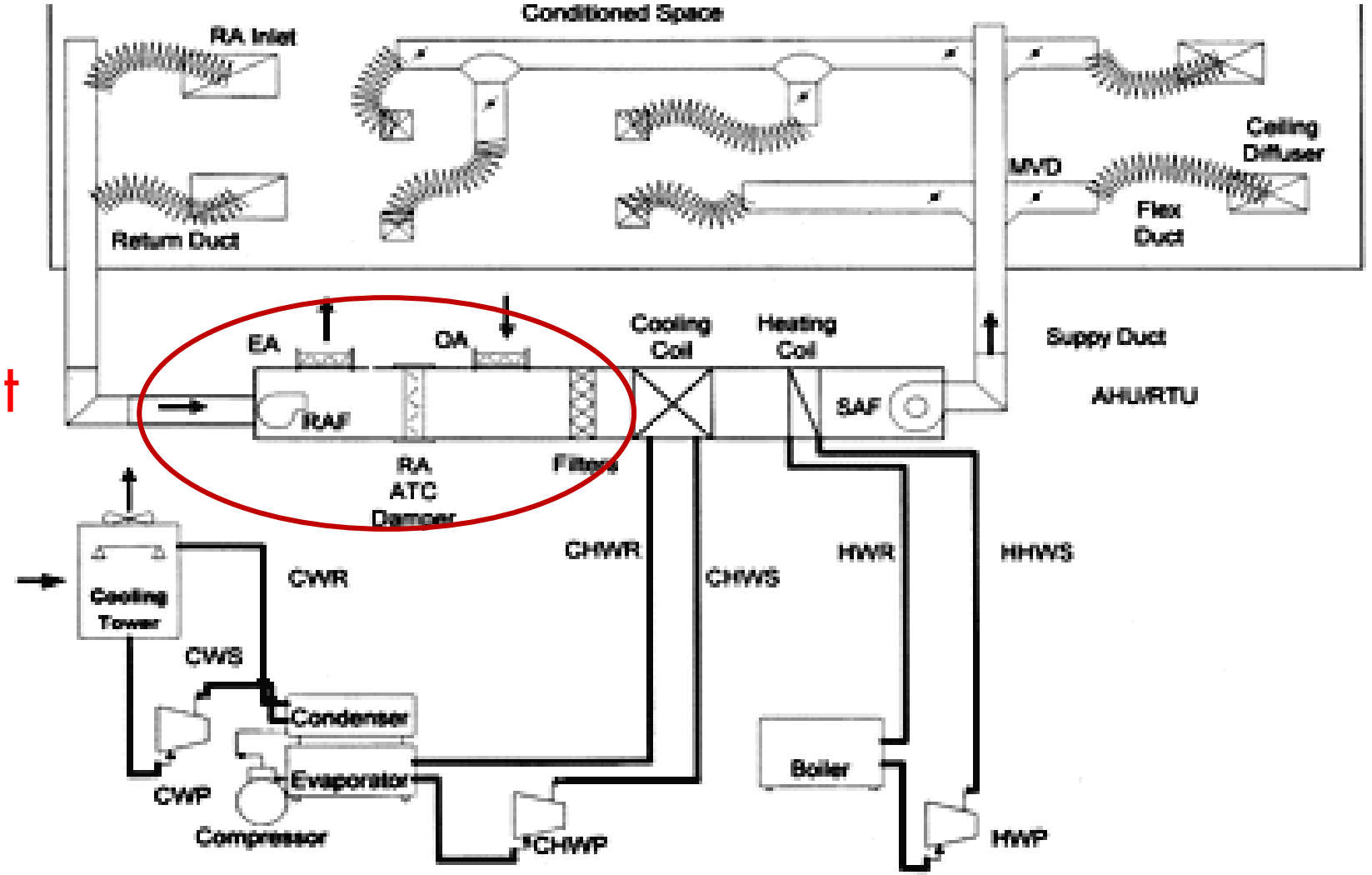
- Heat recovery devices may carry over virus attached to particles from the exhaust air side to the supply side via leaks
- Regenerative air to air heat exchangers (also called enthalpy wheels) may be more sensitive due to commonly improperly installed and commissioned. (shown 20% cross over contamination)
- Carry over leakage is highest at low airflow thus higher ventilation rates are recommended.
- Recommend to inspect and commission with personnel wearing proper personal protective equipment (PPE).
- Virus particle transmission not a concern with heat recovery devices that guarantees 100% air separation.

Recirculation

- Recommend to avoid recirculation completely (close recirc dampers) during episodes of contaminated buildings.
- Even if filters are in the recirc ductwork, they typically do not have the correct Minimum Efficiency Reporting Value (MERV) or HEPA ratings to adequately filter virus.

Typical HVAC Diagram

Typical area in system to adjust Exhaust Air (EA), Outside Air (OA), RA Damper and Filters.



Fan Coil and Induction Units

- Fan coil and induction units work with local (room level) circulation
- Units should be turned off when unoccupied
- The fan coil heat exchanger surface can inactivate the virus by heating up fan coils to 60 degC during one hour or 40 degC during one day

Duct Cleaning

- Is not recommended to address virus transmission: cannot adequately remove virus.

Room air cleaners

- Can be useful
- Need to have at least HEPA filter efficiency
- Because the airflow through air cleaners is limited they can effectively serve usually small rooms
- Filter should be located in the breathing zone

Summary of practical measures for building services operation (from REHVA)

1. Secure ventilation of spaces with outdoor air
2. Switch ventilation to nominal speed at least 2 hours before the building usage time and switch to lower speed 2 hours after the building usage time
3. At nights and weekends, do not switch ventilation off, but keep systems running at lower speed
4. Ensure regular airing with windows (even in mechanically ventilated buildings)
5. Keep toilet ventilation 24/7 in operation
6. Avoid open windows in toilets to assure the right direction of ventilation
7. Instruct building occupants to flush toilets with closed lid
8. Switch air handling units with recirculation to 100% outdoor air
9. Inspect heat recovery equipment to be sure that leakages are under control
10. Switch fan coils either off or operate so that fans are continuously on
11. Do not change heating, cooling and possible humidification setpoints
12. Do not plan duct cleaning for this period
13. Replace central outdoor air and extract air filters as usually, according to maintenance schedule
14. Regular filter replacement and maintenance works shall be performed with common protective measures including respiratory protection

Resources & References

- ASHRAE Position Document on Airborne Infectious Disease
  https://www.ashrae.org/file%20library/about/position%20documents/airborne-infectious-diseases.pdf
- Guidance for Building Operations During the COVID-19 Pandemic
  https://www.ashrae.org/news/ashraejournal/guidance-for-building-operations-during-the-covid-19-pandemic
- COVID-19 Response Resources https://www.ashrae.org/technical-resources/resources
- How to Operate and Use Building Services to Prevent the Spread of COVID-19 https://www.rehva.eu/activities/covid-19-guidance
- Guidance on Preparing Workplaces for COVID-19 https://www.osha.gov/Publications/OSHA3990.pdf
- OSHA ALERT to Prevent Worker Exposure https://www.osha.gov/Publications/OSHA3989.pdf
- *March 9, 2020 – OSHA News Release* – U.S. Department of Labor Offers Guidance For Preparing Workplaces for Coronavirus | Occupational Safety and Health Administration
  https://www.osha.gov/news/newsreleases/region/03092020
- *March 14, 2020 – OSHA National News Release* – U.S. Department of Labor Issues Temporary Enforcement Guidance for Respirator Fit-Testing in Healthcare during COVID-19 Outbreak
  https://www.osha.gov/news/newsreleases/national/03142020
- Informative podcast: "The Domino Effect of Quarantine and Responses to COVID-19: What We Know, What You Can Do."

From Centers for Disease Control and Prevention

- Environmental Cleaning & Disinfection Recommendations
  https://www.cdc.gov/coronavirus/2019-ncov/community/organizations/cleaning-disinfection.html

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Thank You!

If you have questions on this presentation contact

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