INTRODUCTION

- We’re here because of COVID-19, however…
- Role of buildings in infection transmission now widely recognized, will be an issue after pandemic is over
- Goal today:
  - Discuss some COVID-19-specific issues
  - Place HVAC systems in context with respect to infection risk
  - Review HVAC – related infection control fundamentals that can be applied to any building
- Overview of ASHRAE Epidemic Task Force and ASHRAE guidance
3 OUR CURRENT SITUATION RE COVID-19

• Trying to control a pandemic disease when
  • Shedding rate of infectors is not accurately known
  • Infectious dose is not accurately known
  • Viral content of infectious droplets/particles is not accurately known
  • Aerosol/airborne transmission is strongly suspected in some circumstances, but not definitively proved from the perspective of health authorities

…and under tremendous pressure to re-open society
DO WE KNOW ANYTHING RELEVANT TO MANAGING RISK?...YES, BUT INTERPRETATION IS NEEDED

• SARS-CoV-2…
  • is small \( \approx 120 \text{ nm (0.12 \mu m)} \), but carried in larger particles/droplets
  • is very susceptible to UV-C light
• Particles that may contain SARS-CoV-2…
  • are filterable by efficient, but sub-HEPA filters
  • can be removed by ventilation
• Little evidence of aerosol transmission in “properly” ventilated spaces

• Several investigated super-spreading events with common features:
  • High occupant density
  • Inadequate ventilation – measured or suspected
  • Relatively long residence time – dinner, workday
• Possible role of air movement in occupied spaces – possibly extending range of droplet transmission
• Infectious aerosols can penetrate HVAC systems
  • Activity not determined
  • No evidence of transmission from contaminated space to uncontaminated space via HVAC
5 WHAT CAN WE DO?

- Apply established principles of risk management
- Apply existing knowledge about aerosol/airborne disease transmission
- Apply established principles for controlling exposure to air contaminants
- Apply established principles of risk management
- Be willing to change our views based on emerging knowledge
- Recognize that all of the available guidance is a starting point and we are still responsible for applying it
6 INFECTIONOUS DISEASE TRANSMISSION MODES

- Airborne
  - Large droplet/short range
  - Aerosol/airborne
- Fomite – intermediate surface
- Water/food
- Physical contact
- Insect/animal vector

...HVAC mainly impacts aerosol and fomite transmission – only part of a solution
7 SOURCES OF INFECTIOUS AEROSOLS

- Humans – breathing, talking, singing, coughing, sneezing
- Plumbing – toilet flushing, splashing in sinks
- Medical procedures – dentistry, endotracheal intubation, and others
FOUNDATIONS OF GUIDANCE
RESPIRATORY AEROSOL PROPERTIES

- Emitted as droplets
  - Water, proteins, salts…
  - Dehydrate to smaller sizes
  - Process dependent on relative humidity
  - Initial diameter < 1 µm to > 1000 µm
- Infected persons shed viruses in droplets
- Studies of influenza have found > 50% of viral load is in particles < ~5 µm

Duguid, et al. 1945
10 RESPIRATORY AEROSOL DYNAMICS

- “Large” droplets settle before travelling long distances
- “Small” droplets/aerosols remain airborne longer, may travel significant distances
- Various definitions of boundary between small and large —~ 60 µm initial diameter, 10 µm final diameter
COVID-19 TRANSMISSION

- Public health authorities (WHO, national organizations like CDC in US)
  - Transmission is mainly close contact/large droplet
  - Admit some evidence of aerosol transmission
- ASHRAE, REHVA, and other HVAC societies
  - HVAC systems mainly impact aerosol transmission
  - Take evidence of possible aerosol transmission as justification for applying the precautionary principle
THE PRECAUTIONARY PRINCIPLE

“One should take reasonable measures to avoid threats that are serious and plausible.”

RISK MANAGEMENT

• Multiple modes of transmission → multiple controls

• Collaboration gives best results
  • Designers
  • Owners
  • Operators
  • Industrial hygienists
  • Infection control specialists

• Focus here on engineering controls for aerosols
PROTECTIONS AGAINST INFECTION
SOURCE CONTROL FOR COVID-19
MASKS - SOURCE CONTROL OR PPE

• Well-fitted, high efficiency mask protects wearer and others
• Other masks mainly protect others from large droplet spray/aerosol jets generated by wearer

Credit: M. Staymates/N. Hanacek/NIST
doi:10.20944/preprints202004.0203.v2
ENGINEERING CONTROLS

- Ventilation
- Air distribution
- Filtration
- Disinfection
- Temperature and humidity control
VENTILATION AND PRESSURIZATION

- Ventilation dilutes contaminants, increases exposure time required for exposure to an infectious dose
- Effective, but energy intensive, even with energy recovery
- Works in conjunction with exhaust and pressurization to isolate or contain

Figure 4. Associations between common cold infection rates and mean ventilation rate in winter in buildings constructed after year 1993. 1 Proportion of occupants with ≥6 common colds in the previous 12 months.

AIR DISTRIBUTION

- Room air distribution may contribute to risk if it extends distance travelled by large droplets – avoid high velocity discharge in breathing zone.
- Lower velocity mixing may be preferable to displacement.
- Personalized ventilation/exhaust are options in some cases.
Filtration

- Can remove any aerosol contaminant (but not with 100% certainty)
- For indoor sources, requires recirculation in space or system
- Effective if
  - Contaminants of concern are airborne
  - Clean air delivery (efficiency + recirculation) is high enough

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</table>

Representative MERV rated filter performance (Kowalski and Bahnfleth 2002)
Filtration – Infections Aerosol Size

- SARS-CoV-2 size O(100nm)
- Contained in respiratory droplet residues of larger size
- Sub-HEPA media filters can collect particles with high efficiency

Chao, et al., Aerosol Science 40 (2009) 122-133
Filtration can be a lower energy way to reduce aerosol/airborne infection risk.

Relative influenza risk reduction, filters vs. ventilation cost, 500 m² office building.
Filtration has benefits other than infection control.

AIR DISINFECTION – GERMICIDAL UV LIGHT

• Ultraviolet light in UVC band
• 265 nm ideal, 254 nm produced by low pressure Hg vapor lamps is standard
• Disrupts microbial DNA/RNA, prevents reproduction
• Exponential dose response
• Coronavirus susceptibility is good
• Long record of application, CDC approved for tuberculosis control as adjunct to filtration
• Emerging technology – LEDs, far UV (222 nm) from Kr-Cl excimer lamps
GERMICIDAL UV APPLICATIONS

Upper Air UVGI

In-Duct/Coil UVGI

Portable Surface Treatment UVGI
27 SYSTEM EFFECTS – COMBINING VENTILATION, FILTRATION, AND AIR CLEANING

- Combinations of controls can be synergistic
  - MERV rated filter + UV can approach HEPA performance
- Some combinations of controls are mutually exclusive
  - DOAS + central filtration for indoor contaminants
- Some are additive but trade off
  - Ventilation + air cleaning

- Air cleaner effectiveness – describes incremental effect of a control

\[ \varepsilon = \frac{C_{\text{uncontrolled}} - C_{\text{controlled}}}{C_{\text{uncontrolled}}} \]

VENTILATION/FILTRATION TRADE OFF

• Simple example: Ventilation + Filtration
  • Well-mixed, steady state
  • QS = 100
  • S=1
  • CO = 0

• Scenario 1
  • $\eta_F = \text{variable}$
  • 20% OA

• Scenario 2
  • $\eta_F = 60%$
  • f = variable
VENTILATION/FILTRATION TRADE-OFF

20% OA, VARIABLE FILTER EFFICIENCY

60% FILTER EFFICIENCY, VARIABLE OA

Normalized space concentration is relative to value at 20% OA with no filter
TEMPERATURE AND HUMIDITY CONTROL

- Air temperature and humidity influence infection risk
- Several recent studies recommend 40 – 60% RH for infection risk, disease specific - and studies on coronavirus suggest they are more resilient than some
- Possible mechanisms
  - Lower RH → faster droplet evaporation, less deposition
  - Lower RH → desiccation of mucosa by dry air increases susceptibility
  - Lower RH → longer survival/higher infectivity of microorganism
TEMPERATURE AND HUMIDITY

- Possible concerns about humidification and temperature manipulation to control infection risk
  - Different responses for different pathogens
  - Risk of moisture damage/mold growth
  - May reduce effectiveness of UVGI
  - May adversely affect comfort
- No specific recommendation in Infectious Aerosols position document but, practitioners are encouraged to consider on a case by case basis
- ASHRAE Covid-19 guidance for existing buildings bases humidity adjustments on evaluation of system and building limitations
- REHVA Covid-19 guidance – “Humidification and air-conditioning have no practical effect” – based on regional climate and their literature review
ASHRAE ETF OBJECTIVES, STRUCTURE

- Formed in March, 2020

- Objectives
  - Response to COVID-19 pandemic
    - Short term guidance
    - Reopening/2nd wave
  - Plan for the Future
    - Lessons learned
    - Research
    - Standards and guidance
    - Enhanced focus on resilience

- 26 core members, including staff liaison and three staff directors
- Steering committee for teams focused on specific areas ~150 team members
- Coordinate with ASHRAE technical and standards committees, other organizations
ASHRAE ETF FOCUS AREAS (TEAMS) AS OF 7/16/2020

- Communications
- Developing economies
- External partnerships

- Resource inventory
- Literature review
- Science Applications
- Research
- Filtration and disinfection
- Building readiness

- Healthcare (including long-term care)
- Residential
- Commercial/retail
- Schools
- Laboratories
- Industrial
- Transportation
COVID-19 RESOURCES PAGE

Questions? Email COVID-19@ashrae.org

ASHRAE Epidemic Task Force Full Roster
Frequently Asked Questions and Glossary of Terms:

FAQ / Glossary

This page is updated as new information becomes available.
Building Readiness

General Information
- Building Readiness Intent
- Building Readiness Team

Epidemic Conditions in Place (ECIP)
- Systems Evaluation
- Building Automation Systems (BAS)
- Increased Ventilation
- Ventilation Control
- Upgrading and Improving Filtration
- Energy Savings Considerations
- Exhaust Air Re-entrainment
- Energy Recovery Ventilation Systems Operation Considerations
- LVGI Systems
- Domestic Water Systems
- Maintenance Checks
- Shutdown or Building Temporarily FAQ
- Systems Manual

Post-Epidemic Conditions in Place (P-ECIP)
- Post-Epidemic Conditions in Place (P-ECIP)
- Re-starting a building FAQ P-ECIP: Prior to Occupancy
- P-ECIP: Operational Considerations once Occupied
ASHRAE EPIDEMIC TASK FORCE
BUILDING READINESS | Updated 05-21-2020

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• UVGI Systems
• Domestic Water Systems
• Maintenance Checks
• Shutdown a Building Temporarily-FWQ
• System Manual

Post-Epidemic Conditions in Place (P-ECiP)
• Re-starting a building-FAQ P-ECiP: Prior to Occupancy
• P-ECiP: Operational Considerations once Occupied
• P-ECiP: Ventilation
• P-ECiP: Filtration
• P-ECiP: Building Maintenance Program
• P-ECiP: Systems Manual

Additional Information
• Acknowledgements
• References
• Disclaimer

Information in this document is provided as a service to the public. While every effort is made to provide accurate and reliable information, this is advisory, is provided for informational purposes only, and may represent only one person's view. They are not intended and should not be relied upon as official statements of ASHRAE.
General Information

Building Readiness Intent

The following Building Readiness information is meant to provide practical information and checklists for how your building should be operating and how to practically check its operation. Actual conditions at any specific building will vary, and the adjustments that should be made will depend on many factors such as local climate, complexity of systems involved and the use, occupancy and activities that occur in and around your building.

Building Readiness modes of operation for the building should include the following:

- Epidemic Operating Conditions in Place (ECiP)
  - Occupied - at pre-epidemic capacity
  - Occupied - at reduced capacity
  - Unoccupied temporarily, and
  - Operation during building closure for indefinite periods

- Post-Epidemic Conditions in Place (P-ECiP)
  - Prior to Occupancy
  - Operational Considerations once Occupied
BUILDING READINESS – SYSTEMS EVALUATION

- Gather and review building and system documentation
- Inspect equipment, systems, and controls…in that order
- Review and make recommendations regarding HVAC mitigation strategies
- Recommend following ASHRAE Guideline 11-2018 *Field Testing of HVAC Control Components* for controls evaluation
- Prepare deficiency log/work orders
- Prepare report on risk mitigation strategies
BUILDING READINESS – DETAILED GUIDANCE

- Includes discussions of
  - Limitations on increasing ventilation
  - Evaluating ability to operate rotary energy recovery devices
  - Evaluating impact of filter upgrades

**Epidemic Conditions in Place (ECiP)**
- Systems Evaluation
- Building Automation Systems (BAS)
- Increased Ventilation
- Ventilation Control
- Upgrading and Improving Filtration
- Energy Savings Considerations
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- Energy Recovery Ventilation Systems Operation Considerations
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SUMMARY

• HVAC systems can reduce risk of aerosol/airborne disease transmission
• The intent of all HVAC engineering controls is to reduce airborne concentration of infectious aerosol to reduce exposure
• With respect to COVID-19, the quantitative picture is incomplete, but we know enough to take effective and prudent actions based on the precautionary principle
• One definition of what is prudent is measures that have IAQ benefits when left in place
• The repertoire of engineering controls is relatively small but required adaptation to the building and its systems
• ASHRAE guidance provides detailed recommendations for evaluation and upgrading of buildings prior to re-occupancy and specific guidance for various building types
Q & A

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