Safe SARS CoV-2 Indoor Environments – an HVAC engineers' perspective

Recommendations and Case studies, an overview of best practices 11/8/20 Brian Formusa P.E.

1. **ASHRAE and CDC Recommendations are coordinated –** *link to ASHRAE doc:* https://www.ashrae.org/technical-resources/commercial#general
   read the document- it covers a lot of topics I won't cover here.

   "Layering Up"

   a. Social Distancing, Mask wearing most effective measures to first take on. Other methods and technologies do not preclude these primary precautions.
      i. Close contact and spread by close speech/spittle and atomization of virus into air. Thus the mask and 6' recommendations foremost to mitigate but not eliminate.
      ii. The virus can remain suspended in the air and viable for up to 16 hours.

   b. Residence time in a closed room = more exposure. And more people = more exposure. The presence of a carrier, an asymptomatic carrier is the threat.
      All represented by Kevin Van Den Wymelenberg's model.
      -Avoid close talkers!

   "THE KEY TO POLLUTION IS DILUTION"

   c. Outside ventilation air. 10-20 cfm/person minimum code but COVID risk is another level of dilution ventilation required. How's your dilution rate?
      Case study – BCSD schools with DOAS units.
      New gymnasium & Restaurant simply had closed dampers. How to fix.
      YMCA – open up as far as possible, 5 to 30% OSA
      Natural Ventilation: Montessori school and Senior Center.
      DCV- demand controlled vent.
      Air Changes per hour is another metric:

   d. Treating and Filtering air – if possible upgrade to Merv-13. Typical past was Merv-8.
      HEPA (Merv-20). 99% at 0.3um virus is 0.125 um higher the number the better
      – Case study: some equipment can't handle anything more than a MERV 8 or it will malfunction when it becomes dirty. – low airflow. Not break, but be a problem.

   e. Option: Add portable HEPA filters. True HEPA, Thicker and larger the filter media the better. The choices are so many and hype is confusing. I bought Honeywell.

f. Audit your own HVAC systems;
   Or call a pro and ask them to simply do the basics:
   i. Do you have outside ventilation on your HVAC systems? Whats the air intake rate – measure the cfm rate vs. the number of people …and size/use of room(s).
   ii. Look at filters, MERV rating, upgrade it ? See chart below. Are there leak past gaps? Fix that.
   iii. Look at natural cross-ventilation strategies with windows if weather is mild. CASE STUDY – Hailet Senior Center, Montessori School Ketchum.
   iv. Trace the ductwork, which HVAC systems are shared with your office? Are you breathing communal air? Make a change. Add a portable HEPA filter.

g. Humidity 40-60% RH ideal but not normally achievable in this climate if binging in outside air and with a cold climate may incur mold issues in the walls.

h. Housekeeping, cleaning regimens. Not covered here, but essential!

2. **Pathogen Killing Technologies:** *(find a link to our white paper w/Tim Ross, YMC Mechanical)*

   a. Ultraviolet germicidal irradiation (UVGI) is a disinfection method that uses short-wavelength ultraviolet (ultraviolet C or UV-C) light to kill or inactivate microorganisms. Generally impractical to retrofit, potential skin and eye damage if exposed to it. Usually for hvac unit coil treatment.
   Case study – Bob Coplin, neuro-musc. Therapy and UVC LED. Sterilize. Hospital in-room coffers. Coil irradiation. UVC requires residence time, exposure and intensity.

   b. Ionization: Needlepoint Bi-polar ionization. Not new technology but the new generation of low voltage equipment doesn’t produce Ozone which is an indoor air pollutant. Some tests indicate that high (impractical) concentrations (5-10 times higher than those achieved with typical equipment) can have a good virus deactivation rate. Hopefully normally tested (me) lower concentrations actually help. However there is another beneficial effect - ions cause virus particles to agglomerate, become larger and fall to floor or be swept back to filters. +/- ion attraction.

-Smoke mitigation, ionization helps clean the air overall – thus Building codes allow lower vent rates with this equipment.
-Case studies GPS – test cases YMCA, Blaine County bldgs.
-Case studies: found that duct mounted is better than unit/coil… A lot of redo's locally.

c. Other technologies – just be careful of bogus 'test' data or wanna-be valid test results and aggressive marketing departments. Big claims are usually a giveaway.
-Don't hang a sign that says: "Virus free environment" if nothing else it's a false sense of security. tic

The MERV Rating Scale

The air filter rating ranges from 1-20 in the standard MERV chart. The higher the MERV rating, the more efficient it is at pulling articles from the air. As said earlier, a true HEPA filter will be in the top 5 of the MERV scale. You will likely not see too many non-professional air filters all the way at 20, considering they're used in commercial spaces or hospitals.

- *Ratings 1-4*

These are your normal minimal and air conditioning filter that can operate well enough to pull away dust mites and pollen. It isn't enough to take away smoke or mold, though.

- *Ratings 5-8*

This area is more mass-produced for industrial areas, taking out hair spray, cement dust, and other particles that might be harmful to humans. Mold spores are taken by these air filters, but these are more suited for commercial areas as well.

- *Ratings 9-12*

Likely where you'll find most of your quality air filters, this rating area is where you'll find more heavy-duty air filtration. Mechanics, wielders, and superior residential and commercial buildings will employ the use of these air filters. This is also where you'll find most of your HEPA filters if it's not a "true" HEPA filter.

- *Ratings 13-16*

These are the more sterile filter areas that you'll find in general surgeries, hospital inpatient care, and smoking lounges. They will take away most tobacco smoke and all bacteria. This is likely all you'll need if you want an air filter for your allergies and smoking habits. If not, you can likely settle on a 9-12 rating.

- *Ratings 17-20*

While these are the true HEPA filters area, these are mostly used for cleanrooms, radioactive materials, and other pharmaceutical needs. You can put these in your home if you have bad allergy or asthma problems. They take most particles from the air, from carbon and combustion smoke to viruses that might go through the air

References

1. (ASHRAE, 2015). ASHRAE Filtration and Air Cleaning
2. (ASHRAE, 2019). 2019 ASHRAE Handbook HVAC Applications
3. E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, ASHRAE 1985
4. https://www.ashrae.org/technical-resources/commercial#general

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More reference notes

Adequate Code Required Ventilation

ASHRAE 62.1 calculation procedure:

See Tables, default cfm/person about 17 cfm/person

Calcs include; see tables for use of room, People density, room size, overhead vs floor air delivery, DCV

30 x 33 room, 8' ceiling examples:

Office example:
5 people x 17 cfm/p = **85 cfm**

School example:
30 students = **420 cfm**

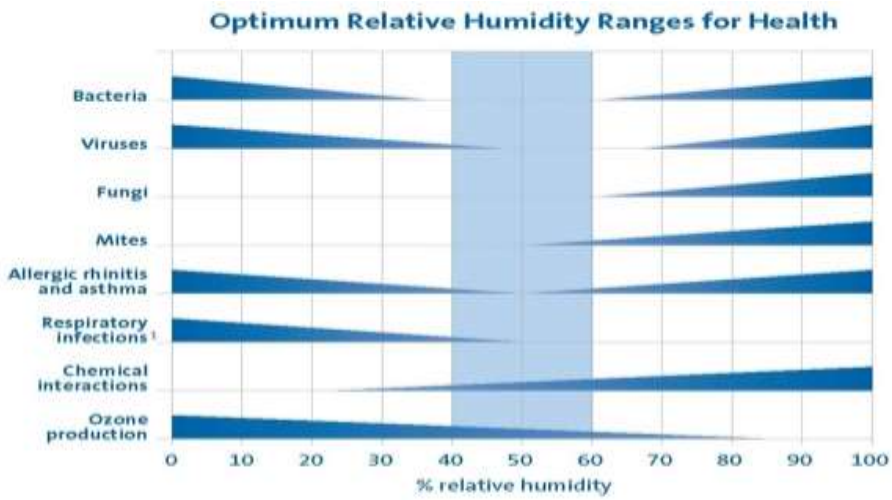
Restaurant:
70 people x 10 cfm/p = **700 cfm**
Cfm OSA = 1000 s.f. x 70 people/1,000sf x 7.5 cfm/p) + (1000 x 0.18 cfm/sf) = **705 cfm**
overhead airflow

Bar/cocktail lounge:
cfm = 1000 sf x ***100p/****1,000 sf* ***x 9 cfm/p*** = **900 cfm**

Air change rate metrics: not a code design tool for people ventilation

Example Space	Air Changes Per Hour	Time Per Air Change	**30x33' room**
Hospital Operating Room	20	3 min	2,400 cfm
Hospital Infection Isolation Room	12	5 min	1,440 cfm
Office w/OA Economizer	5	12 min	
Office w/ASHRAE Min OA	0.8	2 hr	96 cfm
Office w/ASHRAE Min OA @ 50%	0.4	4 hr	

Ex: 30x30x 8'ceilg= $\frac{7200 \text{ cu.ft.}}{\text{A.C.}}$ X $\frac{0.8 \text{ A.C.}}{\text{hr}}$ X $\frac{\text{hr}}{60 \text{ min}}$ = 96 cfm


Optimum Relative Humidity Ranges for Health
Bacteria
Viruses
Fungi
Mites
Allergic rhinitis and asthma
Respiratory infections[1]
Chemical interactions
Ozone production
0
10
20
30
40
50
60
70
80
90
100
% relative humidity

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. *Covid_19 Recommendations for Facilities*

Summary

As workplaces gear up and businesses prepare to reopen during the COVID-19 pandemic, companies are looking to building engineers to provide guidance on how to protect occupants now and during future epidemics. The COVID-19 virus has triggered an unprecedented level of attention to infection control. In most buildings and in most situations, infection control measures including social distancing, isolation of known cases, wearing of masks and hand washing may prove to be considerably more effective than alterations to building heating, ventilation, and air conditioning (HVAC) systems. HVAC systems can be a part of the overall risk mitigation approach but should not generally be regarded as a solution by itself as it cannot address direct or indirect contact routes of exposure.

It is known that virally infected droplets may be transported through ventilation systems, as has been documented for tuberculosis, Q-fever and measles. A virally infected droplet from one person can travel through ducted air pathways, leaky air filters, fans, dampers, and grilles, and end up in other parts of a building. The principal role of HVAC in disease transmission prevention is to remove contaminated airborne nuclei droplets from spaces and reduce the risk of spread to other persons. More likely though is direct transmission from one person to another in through close contact.

There are several types of system alterations available that can provide improvement: dilution ventilation, directional ventilation, UV lights, temperature and humidity, needlepoint bipolar ionization, filtration, etc. However, there are few third-party studies showing the efficacy of the listed strategies. For instance, it remains unclear by how much infectious particle loads must be reduced to achieve a measurable reduction in disease transmission and whether the unknown efficiencies warrant the upfront and operational cost of implementing such control strategies, many of which are capitol cost intensive.

As building owners look to plot their path forward, they would be well advised to seek a multi-layered approach that incorporates several infection control strategies such as:

Strategy	Application Effectiveness	Relative Cost
Filtration	Medium	Lowest
Ventilation	High	Low
UVGI-In Room	Highest	Medium
UVGI-Duct & Air Handler	Medium-High	Medium
Humidity	Medium	Medium-High
Ionization	Medium-Low	Medium-Low
Directional Ventilation	Medium-Low	Highest

Filtration

For filters to have any impact on infectious disease transmission, transmission must occur through the airborne route. With airborne diseases there is limited scientific evidence of direct benefit through improving air filtration, but some reduced exposure can reasonably be inferred based on the ability of high efficiency filters to remove some infectious particles. Systems utilizing HEPA filters are specially designed for this purpose and typically a retrofit with existing HVAC equipment is not possible due to fan limitations. Most HVAC systems have MERV 8 filters or less efficiency. The highest typical filter upgrade within a standard HVAC system would be a MERV 13 filter. This filter is rated to capture 90% of particles of 1 µm and larger. ASHRAE recommends improving central air filtration to MERV 13 or the highest compatible with the filter rack.

Ventilation

It is no surprise to anyone that fresh air is good for the health and wellbeing of a person. Increasing outdoor air ventilation (use caution in highly polluted areas) can provide increased benefits to the occupant and increase the effective dilution ventilation per person at a low initial cost. With infectious diseases, dilution is a solution and increasing building ventilation has shown in studies to lower overall airborne disease transmission risks.

"THE KEY TO POLLUTION IS DILUTION"

Energy-conserving strategies that reduce annualized ventilation rates, such as demand-controlled ventilation, should be disabled, especially during mild outdoor conditions when the additional ventilation has low operating cost.

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Office w/ASHRAE Min OA @ 50%	0.25	4 hr

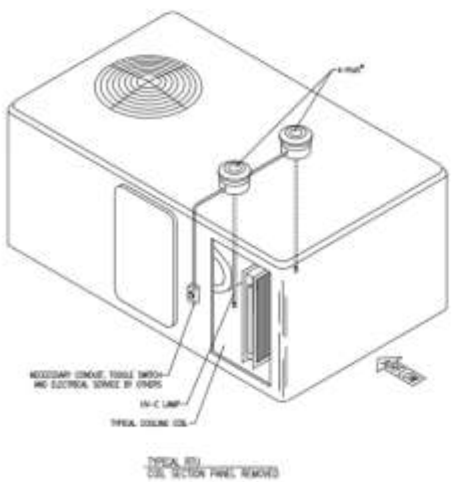
Buildings that have the ability for natural ventilation (operable windows) on appropriate days should allow for the use of these systems if good airflow is possible. Cross ventilation of the room should be targeted by opening windows or doors on opposing side of the building and capturing prevailing winds. Naturally ventilated buildings typically have higher amounts of outside air than conventional HVAC systems employ.

Increasing ventilation can be done relatively easily and the amount of increase is limited by the equipment heating and cooling capacity. However, increasing outdoor air volumes will increase annual energy costs which in colder climates can cost as much as $1/cfm/year.

Likewise, running the HVAC equipment for longer than normal hours helps flush the building of contaminants during the night.

UVGI

Ultraviolet germicidal irradiation (UVGI) is a disinfection method that uses short-wavelength ultraviolet (ultraviolet C or UV-C) light to kill or inactivate microorganisms. This is usually accomplished with lamps that resemble flourescent lamps with a blue hue. There are two UVGI strategies for general application: (1) installation into air handlers and/or ventilation ducts and (2) irradiation of the upper air zones of occupied spaces. The application challenge is to ensure the targeted organism is exposed to sufficient UV dose in the available space and time of UV exposure. Factors impacting dose inlcude: spatial constraints, airflow volume, speed, temperature, humidity and UV device geometry and intensity. Given this information, UVGI system designers can make reasonable and responsible performance estimates for most applications. The greatest disadvantage to UV systems is their operational costs and annual bulb replacement costs when compared to other strategies.



UVR-UV Resources Coil Irradiation

(1) Duct/air handler mounted UVGI can be compared to filtration in the central ventilation system because it inactivates the potentially infectious organisms while filtration removes them.
Air handlers can be a source for contaminants since it provides a source of food (dirt) as well as an ideal environment (damp and low temperatures) for the growth of microbial life. UVGI can be applied to coils within the air handler to disenfect their surfaces and keep bateria from being distributed throughout the building.

Aero-Logic In-Duct Irradiation

(2) Concerns about the safety of in-room UVGI applications on human beings have been an issue since the introduction of this technology for practical use in the 1930s. Careful application of upper-room UVGI can be achieved without an apparent increase in side effects of accidental UV overexposure.

In-room UVGI fixtures are typically mounted at least 7 feet above the floor, allowing at least an additional 1 ft of space above the fixture for decontamination to occur as shown above. The owner should also consider the positive and negative placebo effect present when implementing UV-systems that are visible and or overtly noticeable.

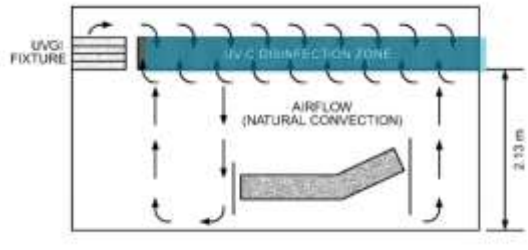


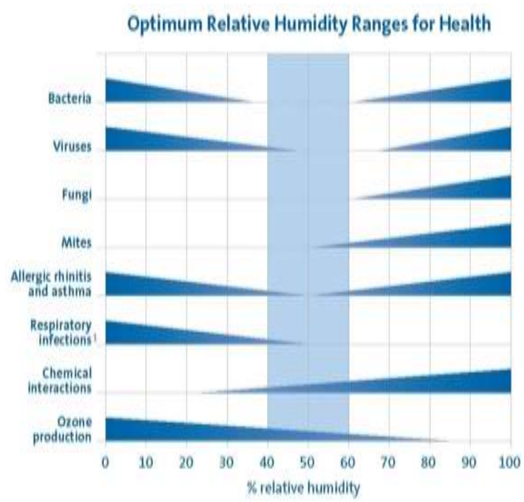
Fig. 5 Typical Elevation View of Upper-Room UV Applied in Hospital Patient Room

(ASHRAE, 2019)

Humidity

Colds, flu, sore throat, dry eyes, itchy and cracked skin are all symptoms that are usually prevalent in the cold dry months of the winter when the indoor relative humidity (RH) is at its lowest. The weight of evidence at this time suggests that controlling RH can reduce transmission of airborne infectious organisms.

Researchers suggest that three mechanisms could potentially explain the observed influence of humidity on transmission: (1) Lower humidity more rapidly changes large droplets into smaller droplet nuclei allowing less viral nuclei to fall to the surface and leaving pathogens suspended longer in the air and available for transmission to others. (2) 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. (ASHRAE, 2015)



E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, ASHRAE 1985

Humidifiers can be attached to existing ductwork and blow moist air into the system, raising the relative humidity. These devices are necessary in the cold and dry winter months of Idaho to maintain RH levels around 50% as recommended. In dry environments common to Idaho it is often a challenge to achieve average humidification levels of even 35% due to constant ventilation air turnover and that building components tend to absorb and transpire moisture readily.

Condair High Pressure In-Duct Humidifier

Ionization

GPS Needlepoint Bipolar Ionization

This technology uses an electronic charge to create a plasma field filled with a high concentration of + and – ions. The ions attach to particles, pathogens, and gas molecules and kill pathogens by robbing them of life-sustaining hydrogen. The ions breakdown harmful VOCs into harmless compounds like O_2, CO_2, N_2 and H_2O.

Recent 3rd party testing results showed that with an average ion density of 27,000 ion/cc in the test space, 99.4% of the SARS-CoV-2 virus located on a stagnant surface was deactivated by technology in a 30-minute timeframe.

Initial testing has demonstrated the ionizers ability to neutralize pathogens on a static surface. Further studies are required for reproducibility of tests, and the efficacy of the technology on airborne pathogens especially in actual field applications.

There are numerous experimental studies regarding the effects of exposure to air ions on respiratory performance and symptoms with the results not being entirely uniform.

Directional Ventilation

Air movement may either increase or reduce exposures to people near sources of contamination. The concentrations in a room with a contaminant source will vary as cross drafts push the contaminant in multiple directions with concentrations being highest in the direction of cross draft. As the cross draft moves along it will tend to mix with surrounding, cleaner air. For that reason, the concentrations may fall with increasing distance from the source. Various distribution methods can be employed to minimize air mixing and cross contamination across spaces.

Normally directional ventilation is a strategy that needs to be implemented during design and construction with there being limited ability to retrofit HVAC systems to do so effectively. However, opening windows and cross-ventilating spaces can achieve much of this plunger-effect to push contaminants out of the space.

References

5. (ASHRAE, 2015). ASHRAE Filtration and Air Cleaning
6. (ASHRAE, 2019). 2019 ASHRAE Handbook HVAC Applications
7. E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, ASHRAE 1985

Disclaimer

YMC, Inc. is providing this information as a service to the customer to briefly discuss available options. We welcome further discussion on any of the items above. Furthermore, YMC, Inc is not infectious disease transmission experts nor industrial hygienists. All strategies and statements in this document should be verified by each individual or organization using their own sources of information.

Respectfully Submitted

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