The Path to COVID-19 Recovery
How to improve indoor air quality when reopening K-12 schools
Webinar on May 28,2020

Q&As

Answers provided by:
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Air Quality & Transmission

1) What is your opinion on continued breathing CO2 thru a mask? Will this make a person sick?

CDC/NIOSH has studied CO2 retention of N95 respirators (see link). While we are not experts on this topic, it is our understanding that cloth face masks tend to be more porous, their fitting is also different from a N95 respirator because of the lack of a cavity. For these reasons,the buildup of CO2 over time from wearing cloth face masks is not a concern.
Source: https://www.cdc.gov/niosh/topics/flu/respiratory.html

2) Does either speaker have a definitive position on the use of masks or respirators to minimize COVID spread?

While we are not experts on this topic, our understanding of the latest research and following CDC guidance is that yes, the use of face masks is an effective way to reduce COVID19 transmission. Face masks act as a barrier and block the expiratory jets of respiratory aerosols from an infectious person.
Source: https://doi.org/10.1098/rspa.2020.0376

3) You mentioned the Li et al (2007) study; would you recommend any other studies to understand the potential relationship between HVAC systems (ventilation, filtration, humidity) and COVID-19 or other airborne pathogen transmissions?

Li et al. (2007) is a review article on the "role of ventilation in airborne transmission of infectious agents in the built environment," largely based on studies of reported cases of outbreak of an airborne disease and its association with building ventilation. A paper by Smieszek et al. (2019) modeled aerosol transmission on the spread of influenza and showed that ventilation is an important factor in a school setting. A paper by Azimi and Stephens (2013) modeled the impact of HVAC filters on influenza risks in an office environment and found high-efficiency air filters (MERV 13+) can lower risk of transmission. Re: humidity, Lin and Marr (2020) found that viruses survived well at relative humidity lower than 33% and at 100%, but their viability was reduced at intermediate relative humidity.
Sources: https://doi.org/10.1038/s41598-019-38825-y
https://doi.org/10.1016/j.buildenv.2013.08.025
https://pubs.acs.org/doi/abs/10.1021/acs.est.9b04959

4) Is there a risk in spreading bacteria or viruses present on surfaces if your moving the air with a higher than recommended cfm,

Generally when you increase outdoor air entering an HVAC system you do not increase the overall supply air rate. The supply air is the sum of return air and outdoor air. When you increase the outdoor air you decrease the return air, and the excess air is exhausted from the building from an exhaust fan or pressure relief. We are not recommending increasing the total supply airflow rate.

5) "A slide noted that ""10 of the 40 studies reviewed were conclusive on the association between building ventilation and the transmission of airborne infection."" Did the other 30 studies not address that issue? Were they inconclusive? Or did they definitively not show an association? "

From Li (2007): "Of the 40 studies, 18 were considered as non-conclusive or not having met the evidentiary threshold to support a direct contributory role of ventilation rate/airflow pattern to the airborne spread of infectious agents, 12 were considered partly conclusive or met the threshold somewhat, and 10 were deemed clearly conclusive as supporting a direct contribution. Taking an overall perspective, we believe that there is a strong and sufficient evidence in the current literature to demonstrate a definite association between ventilation and airflow patterns in the indoor environment and the transmission of infectious diseases. Responsible agents cited include measles, TB, chickenpox, influenza, smallpox and SARS."
Source: https://doi.org/10.1111/j.1600-0668.2006.00445.x

6) A: What about the increase in distance from ventilation streams that are horizontal? The study from the China restaurant showed that flow from the HVAC increased the distance that the droplets traveled and resulted in transmission of Covid 19.
B: Glad you are showing the China study. If the exhaust fan were operating in the left side of your slide were operating, the lateral transmission from right to left would still have happened.

When a sufficient amount of outdoor air is introduced into the building, the indoor concentration of contaminants, which includes circulating viruses, are reduced. For example, in a classroom with a volume of 10,000 ft^3 and an outdoor air ventilation rate of 450 CFM, the air in the room will be changed out once every 22 minutes, or approximately 3 times per hour. Filtration can also reduce the amount of airborne particles. While airflow patterns could still impact transmission, if the indoor air is filtered and diluted at the appropriate rate with outdoor air, there is a lower risk to all room occupants, regardless of occupant location and airflow patterns.

7) What is the size of a Covid particle?

The virus particle itself is about 0.1 microns in diameter. However, the virus particles are contained inside respiratory droplets and aerosols suspended in the air. These droplets and aerosols are larger in size (1 to 100 microns, depending on a range of factors), and may be removed by filtration.

8) It was recommended that occupied indoor air temperatures be maintained between 68 and 78 is recommended, and that high ventilation rates support improved student performance. We are looking at potentially sacrificing the cost of cooling to pay for the added expense of providing greater ventilation. Please offer some perspective on the relative rates at which student performance would decline when indoor air temperatures rise above 83 F but remain at 800 CO2 versus remain below 78F but CO2 levels above 1200.

Both thermal condition and indoor air quality matter to our learning environment; see Wargochi and Wyon (2017). The goal should be to achieve conditions as close to optimum range as possible. For ventilation, 1000 ppm is the target per ventilation standard. Air temperature between 20C (68F) and 25C (78F) are recommended. We do not recommend trading off one with another, but rather think of alternative strategies (reduce the number of occupants?) to supplement HVAC.
Source: http://dx.doi.org/10.1016/j.buildenv.2016.11.020

9) Is there any evidence that displacement systems further help reduce contaminants in the breathing zone? (They help ventilate better since ASHRAE allows a 1.2Effectiveness, but what about contaminants)

Airflow direction can have a large impact on controlling contaminant transports within a room and between different zones of a building. But in practice, it is often challenging to achieve design goals. Based on experiments and computer (CFD) simulations, Qian and Zheng (2018) showed that mixing ventilation and downward ventilation is preferable over displacement ventilation. This is because: "[l]arge temperature gradient (usually in displacement ventilation) and great momentum of exhaled jet enlarge the spreading distance of short-range airborne transmitted diseases, which brings a higher risk in short-range airborne transmission than in long-range airborne transmission."
Source: https://dx.doi.org/10.21037%2Fjtd.2018.01.24

10) Great presentation and good CO2 ventilation recommendation --ASHRAE miss IMO. The recommendations for education are applicable to all public buildings with healthcare having a higher standard. Is monitoring for VOCs really necessary if building ventilation standards are met or exceeded (any empirical data)? Similarly, in areas where there are periodically high levels of ground level ozone would the increased fresh air ventilation benefits be negated by introducing ozone? Best mitigation strategies?

We are recommending measuring carbon dioxide (CO2) concentrations to detect potential ventilation system failures. We are not recommending monitoring for volatile organic compounds (VOCs). Regarding Ozone, a study we completed in 2019 (report still pending) found indoor ozone levels in two schools in California (Sacramento and Bakersfield regions) to be well below the annual average standard of 70 parts per billion (ppb). Indoor average ozone levels measured 8-22 ppb compared to outdoors (30-41 ppb). Generally concerns about ozone do not mitigate the overwhelming benefits of outdoor air.

HVAC Systems & Operations

11) Bard units are also used in hard classrooms, not just portables

Yes thank you for pointing that out.

12) In your experience, which takes precedence for ventilation rates: ASHRAE or State building requirements?

The specific State building code minimum must be followed. Many State building codes are built upon ASHRAE recommendations. If your State building code and ASHRAE recommendations are not the same, I would **err on the side of providing the higher ventilation rate**.

13) What do you think about the CDC recommendation for using direct steam injection for humidification instead of media pads, spray trees, and ultrasonic?

I am not familiar with the recommendation, but suspect it arises from concerns regarding mold, bacteria, legionella, etc in the sump of the humidifier. This could be a concern because it would be difficult for a district to clean and maintain distributed portable humidifiers. The concern with direct steam injection/warm mist humidifiers is that they are energy intensive.

14) A: Is there any guidance that mentions HVAC operations in buildings with plenum returns (most schools)?
B: Room to room transfer is possible where there are plenum returns. This is why only ducted returns are allowed in facilities where infection control is a main concern (hospitals) obviously, schools have not had this concern built into design standards.

I assume the concern being raised here is the situation where air from multiple classrooms mixes into a common return. If these are single zone HVAC systems (one HVAC system per classroom), it could be possible to duct each return to each dedicated HVAC system. If this is a multi-zone HVAC system serving multiple classrooms, it is impossible (with replacing HVAC systems) to avoid mixing return air from multiple classrooms. In this case the only option is to increase the outdoor air fraction or filtration levels, or both. It would be wise for the school administration to understand which classrooms share HVAC systems so they can consider the minimal (but possible) transmission risk between cohorts of students when contact tracing.

15) Does air direction in classrooms critical?
Theresa should we also deal with the direction of airflow (horizontal vs. from high to low)?

I don't think there's sufficient evidence on whether airflow patterns could reduce transmission. For existing schools it's impractical to redesign airflow distribution in a short timeline with limited budgets with unknown benefits. A few things seem practical. If you have a duct distribution system, make sure that it's balanced. For example, if you have 4 supply airflow registers in a classroom, make sure they are all delivering equal airflow (within 10%). Make sure none of the registers are obstructed. This will improve the overall distribution of the ventilation air to the classroom. Second, for wall-mounted supply

airflow registers, make sure they are balanced and not obstructed and that they are above the heads of the occupants.

16) Theresa is recommending to run HVAC indoor fan continuously during the day. When I do this it increases humidity in the classroom. Especially on newer 410A units. What is recommended for an issue like this?

You need to operate indoor fans continuously to provide ventilation to the classroom - it is imperative for student health and learning. I assume you are in a humid climate and it's the outdoor air coming in that's increasing humidity. First, measure your outdoor rates and ensure that you are not unintentionally over-ventilating. Second, check your supply air temperatures in cooling mode and make sure your refrigeration system is working correctly. Check your supply air flow rates and make sure they are in the desired range. You could lower your supply airflow rate slightly in cooling to increase dehumidification of the air. Discuss these concerns with a qualified test and air balance contractor: https://wcec.ucdavis.edu/wp-content/uploads/TAB-Technical-Report-051220.pdf

17) A: Although we don't know exactly how much ventilation is needed to reduce transmission is it scientifically supported to say that more ventilation is good?
B: While indoor IAQ suggests more OSA is always better, what considerations are factored in as it relates to PM2.5?

In terms of diluting indoor emitted pollutants (including respiratory aerosols that are potentially infectious), yes, research suggests that higher ventilation is better. This is one reason why high risk spaces like hospitals are required to have higher ventilation rates. But, in situations where we are taking precautionary steps to reduce risk of transmission such as in classrooms, then more outside air is not always better if there is a concern that the outdoor air is unfavorable: too hot, too humid, contains particulates, etc. In these cases, we have to make sure that the existing HVAC system can condition and filter reliably. This is why we recommend focusing on making sure HVAC systems are providing the minimum ventilation required and using economizers to increase ventilation when conditions are favorable.

18) Is fine particulate introduced from outdoor air an issue or is this mitigated with proper filtration? Is VOC generally not a concern if pre-purge scheduling is observed along with keeping ventilation adequate to control CO2 within desired range? Are there any concerns about ozone being introduced from outdoor air when outdoor air quality is poor?

MERV 13 filters combined with the ventilation rates recommended for classrooms should mitigate outdoor air particulates in almost all but the worst circumstances (e.g. wildfire events). VOCs are generally mitigated by pre-purge scheduling and ensuring ventilation rates are met. Regarding Ozone, a study we completed in 2019 (report still pending) found indoor ozone levels in two schools in California (Sacramento and Bakersfield regions) to be well below the annual average standard of 70 parts per billion (ppb). Indoor average ozone levels measured 8-22 ppb compared to outdoors (30-41 ppb). Generally concerns about ozone do not mitigate the overwhelming benefits of outdoor air.

19) You may want to shut down the HVAC during night because you may be disinfecting school during that time. It all depends on the situation.

Generally providing ventilation during disinfection would be a benefit to exhaust cleaning products. Here's the recommendation from CDC: "Cleaning products should not be used near children, and staff should ensure that **there is adequate ventilation** when using these products to prevent children or themselves from inhaling toxic fumes." It is important to note that some disinfectants are asthma triggers, so schools are recommended to follow best practices.
Source: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/schools.html

20) Any recommendations on ventilation during unoccupied hours and prepurge during morning startup

Turn ventilation system on 2 hours prior to scheduled occupancy.
Source: https://www.ashrae.org/technical-resources/resources

21) In many California Schools, mechanical ventilation is accomplished with fixed HVAC units that have fixed OA dampers (no economizers). In urban areas such as Los Angeles, OAir Quality is also poor. How do you recommend increasing ventilation in these cases?

Adjust the fixed outdoor air dampers to provide 15 CFM per person or retrofit with economizer controllers. Add MERV 13 filters to reduce exposure to outdoor pollutants. In a study we completed in 2019, we demonstrated in both Sacramento and Bakersfield that using MERV 13 filters compared to MERV 8 filters reduced indoor PM 2.5 concentrations by an average of 40%. Health risks from outdoor pollutants are one reason not to attempt to exceed the 15 CFM per person ventilation target.

22) With BPM/ECM motors set to maintain airflow the watt draw will go up as you stated.

Agreed. In a study we completed in 2019 (report still pending) we found over the course of a year where we changed the filters 1 time during the school year, using slightly higher pressure drop MERV13 filters compared to MERV8 filters consumed an additional 20 Watts on average over the ensure school year.

23) Regarding economizers - how often is outdoor air favorable for cooling in CA when classes are in session?

A LOT. We completed a study in 2019 (report still pending) of side-by-side comparisons of economizers with demand control ventilation to constant rate ventilation classrooms. The study used building models validated by year-long energy monitoring in two climates. Overall the energy savings from the economizer and demand control ventilation strategy (ECON-DCV) was 13-43% (see table below). Most of the savings is due to the economizer and not the demand control ventilation (particularly in the secondary classrooms which have high occupant densities).

	ECON-DCV – Elementary kWh saved (percent)	ECON-DCV – Secondary kWh saved (percent)
Sacramento	305 (26%)	268 (20%)
Bakersfield	228 (20%)	199 (15%)
Riverside	172 (16%)	163 (13%)
Tahoe	916 (43%)	705 (32%)

24) Slide 31 - Ventilation prior to occupancy at Maximum Possible rate? Is that what it is designed for for full occupancy or even more? Can you please clarify. Also important to keep tab of OA dew point

Revising this statement - Ventilate two hours prior to occupancy at the design rate.

25) Are ceiling fans or floor fans that circulate the air helpful or harmful for infectious disease spread?

They could possibly be harmful by increasing air circulation among students. But the effects of airflow on the transport and fate (such as deposition onto surfaces, resuspension from human activities) of respiratory aerosols remain an active area of research, so it is difficult to say what overall impacts ceiling fans or floor fans will have on transmission. Ways in which fans could be helpful would be if they are being used to increase the outdoor air exchange rate (e.g. a fan placed in a window).

26) Do older heat pumps potentially bring in worse air quality than originally designed for? (Does the machine contribute potentially to poor air quality?)

No not at all. Heat pump efficiency has improved but all the basic operating principles are the same.

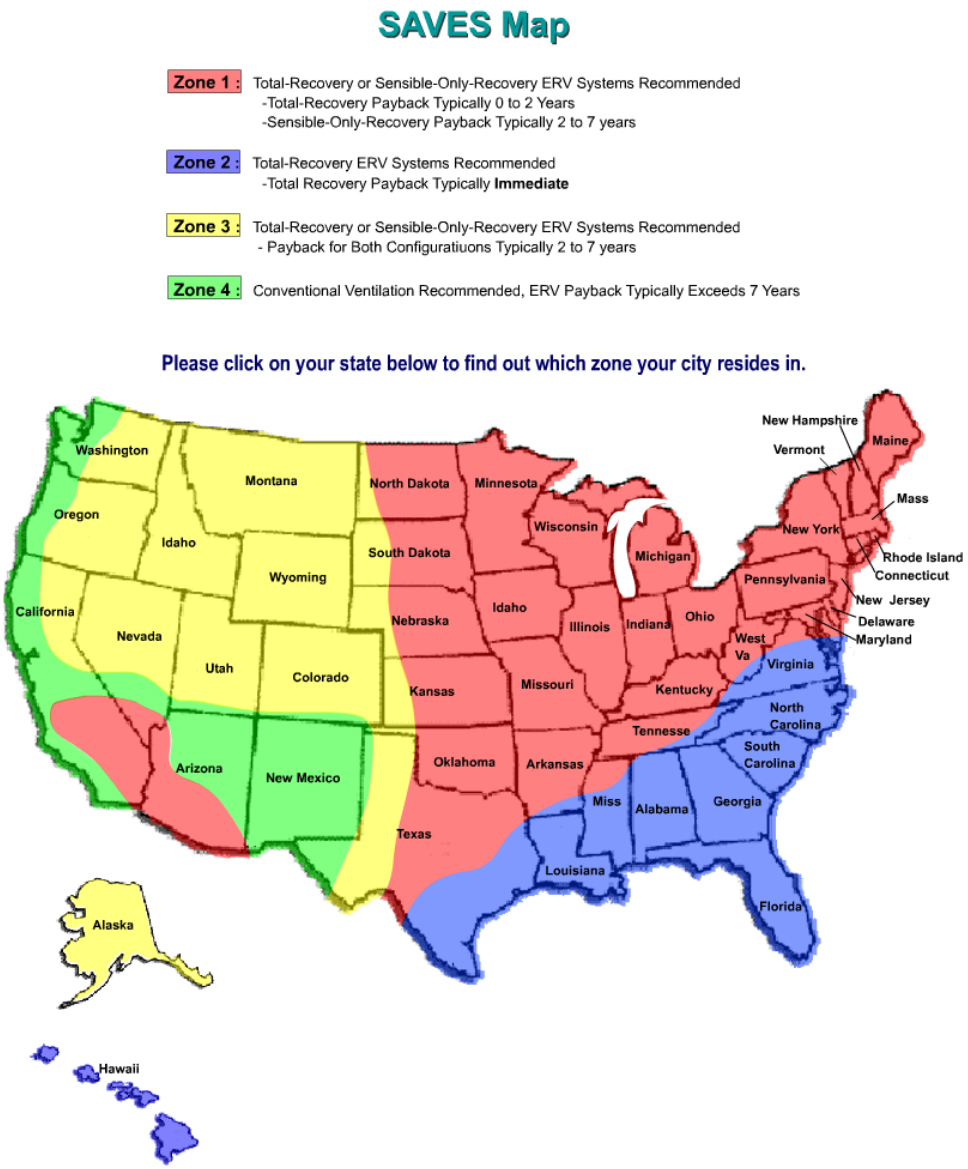
27) Heat pump is on, thermostat at 78 degrees F and the situation comfortable near 2 pm. If I turn the thermostat to 80 degrees F, during SMUD's Time of Use higher rate, from 5-8 pm, the air starts to feel stale/unhealthy, even if the heat pump is still going on. Last night near 8 pm, inside was 78 F, but outside air upwards of 90 F seemed healthier.

It is very helpful to monitor CO2 concentrations which will tell you if you are delivering adequate ventilation to a space. Temperature does not tell you the entire story. You can also monitor particulate matter concentrations (PM2.5) using low-cost sensors indoors and outdoors as well.

28) The discussion should have mentioned that there are heat/energy recovery ventilation systems that reduce the energy needed for heating or cooling incoming ventilation air. Some of these systems are available as per-classroom units that can easily augment existing HVAC systems.

Energy recovery is very useful in certain climates. There are a few concerns:

1) ASHRAE is recommending **to not use energy recovery** *wheels* in the pandemic because the wheel spinning between the supply and exhaust air streams can transmit contaminants between the exhaust and supply air streams. The concern is that any material that has latent heat transfer (i.e. water) may also transmit virus particles between the supply and exhaust streams. Plate heat exchangers that are not permeable to water and other indirect types of energy recovery where there is no transmission of air or moisture between the exhaust and supply air streams are still okay. But this rules out many individual classroom energy recovery ventilators.
2) Because classrooms are cooling dominated, in mild climates energy recovery devices may actually increase energy use when compared to an economizer. Most energy recovery devices do not have a bypass option and there are hours where an energy recovery device may be heating air when it is undesirable. See the following map from the The School Advanced Ventilation Engineering Software (SAVES) which shows areas (red, purple) where energy recovery is most strongly recommended from an energy perspective. For more information: https://www.epa.gov/iaq-schools/school-advanced-ventilation-engineering-software-saves#ERV



29) Recommendations to improve IAQ for classrooms with split AC systems

A classroom with split AC systems hopefully still has a mechanical ventilation system. If not, opening doors and windows on opposite sides of a classroom may achieve sufficient ventilation. Monitoring CO2 concentrations will show whether or not natural ventilation is reliable enough. The best long-term solution would be to add a dedicated outdoor air system (DOAS) for the purpose of providing ventilation. Generally these are configured so that one DOAS system serves a group of classrooms.

Restrooms

30) A: What is the rationale of running the restroom exhaust fans 24 hrs/day?

B: Typical operation is to turn off exhaust fans when building is not occupied especially in high humid environments. Theresa indicated we should run restroom exhaust fans 24 hours a day for schools.

C: SHould we only run exhaust fans during building occupied hours only in high humidity environments?

D: 24/7 exhaust is a bad idea if HVAC/makeup air is off. Brings in untreated air into space & can lead to mold.

Running exhaust fans 24 hours was a recommendation in the ASHRAE guidance for schools and we are not entirely certain as to the logic behind the recommendation. One reason is that interior restrooms might connect to adjacent indoor spaces and keeping exhaust on continuously will prevent air traveling from restrooms to adjacent spaces. Another reason is restrooms might be used for longer hours (e.g. after school services, a teacher staying late). Some good points have been raised that running exhaust in the absence of make-up air could be a problem for humid environments. It seems reasonable to shut off exhaust fans when you shut off makeup air systems.

Energy Costs/Costs

31) A: Some colleges have decided to take 100% outside air this coming fall as one of the measures to reduce COVID-19 risk. As indicated in the CDC guideline, "outdoor air as much as possible". In your opinion, is this an effective measure, consider the energy cost associated with conditioning all the outside air.
B: Have you done any analysis of the increased energy resulting from increased ventilation.

The energy impacts will vary significantly by climate zone and by the amount of outdoor air. The energy impacts could be extreme depending on the climate. Consider retrofitting economizers and economizer controllers onto as many systems as possible - this will allow you to bring in 100% outdoor air when conditions are favorable which will both improve indoor air quality and save energy.

We are only recommending increasing ventilation to meet State or ASHRAE 62.1 guidelines, and so while this may increase energy use it's necessary to meet basic IAQ standards.

32) A lot of the information I am reading about ventilation and virus spread prevention recommends increasing outside air intake. Would introducing more outside air through mechanical ventilation increase construction cost significantly?

I would not expect that this would increase new construction costs. The best approach would be to make sure that all new HVAC systems have economizers that are capable of bringing in 100% outdoor air when conditions outside are favorable.

General Ventilation

33) Is the State of California, i.e. the CA Department of Public Health or the California Department of Education actively implementing programs to improve ventilation rates in our public schools?

We are not aware of any current programs, but would encourage these organizations to consider funding a program targeted at this effort. Theresa participated in drafting the guidelines for a potential program and it is available here: https://wcec.ucdavis.edu/improving-indoor-air-quality-in-california-schools/

34) What is the biggest barrier to schools keeping them from providing proper ventilation and clean air for students?

The biggest barrier is a lack of awareness and acceptance that this is a problem and that it is a high priority (has big impacts on student health and learning). Ventilation is not well understood by the general population and you can't "see it." Teachers/students/parents can see when classrooms are not clean, they can tell when a classroom is too warm or too cold. A lack of ventilation has health and learning impacts but it's sneaky - teachers can be in a severely under ventilated classroom and think that their indoor air quality is "fine." This is why CO2 sensors are so beneficial, they provide hard data on whether or not ventilation targets are being met. Schools could also be worried about the potential liability of installing CO2 sensors because of the concern of uncovering problems with mechanical ventilation systems that they can't afford to fix.

Ventilation Considerations

35) Down in North Carolina humidity is our never ending foe. Increased ventilation will be a new battle.

Generally speaking I would expect most HVAC systems will be able to accommodate mechanical ventilation of approximately 15 CFM/person even in areas with high humidity. We caution about trying to increase beyond design rates (15 CFM/person at full occupancy) because of equipment limitations and energy use considerations.

HVAC Filters

36) Is MERV 13 a recommendation or a mandate? They are double the cost...
You need to consult your local regulations (e.g. State) for any mandates. We are recommending MERV13 filters. Even though they are double the cost this equates to an additional ~$20 per year per classroom. This is an excellent return on your investment in our opinion.

37) What MERV rating is a HEPA filter? Is it 22 or closer to MERV 13?

A HEPA Filter has a MERV rating greater than 16. See table from ASHRAE handbook:

		Average particle size efficiency (PSE)		
Group	**MERV rating**	**0.3–1.0 µm**	**1.0–3.0 µm**	**3.0–10.0 µm**
1	1			<20%
	2			<20%
	3			<20%
	4			<20%
2	5			20–34.9%
	6			35–49.9%
	7			50–69.9%
	8			70–84.9%
3	9		<50%	≥85%
	10		50–64.9%	≥85%
	11		65–79.9%	≥85%
	12		80–89.9%	≥90%
4	13	<75%	≥90%	≥90%
	14	75–84.9%	≥90%	≥90%
	15	85–94.9%	≥90%	≥90%
	16	≥95%	≥95%	≥95%
HEPA		≥99.97%	≥99.97%	≥99.97%

source: ASHRAE Handbook

38) Most MERV 13 filters are very restrictive on airflow. What CFM did your pressure data come from?

Not all MERV13 filters are the same, pressure drop varies. All the pressure drops shown in the table were measured at the same face velocity which was 295 ft/minute. So for a 2'x2' filter that would be ~1200 CFM.

39) What about 4" deep filters?

If your equipment accommodates this, fantastic. It will reduce pressure drop and the time required between filter changes (because the filters will have greater surface area).

40) Increased pressure drop from filters will reduce fan watt draw for PSC motors (flow goes down)

Agreed, clarifying that it will increase for electronically commutated motors (ECM) that are constant flow (speed increases when resistance increases). For a PSC motor both the airflow rate and power will drop as the filter loads.

41) What MERV filter rating is recommended for HVAC systems to filter sub-micron particles the size of viruses? I have heard MERV 11 and MERV 13. Does MERV11 do the job? If so, I would think MERV 11 would be recommended because it will provide less air flow resistance and need changing less often than MERV 13. Is there a recommendation on MERV filter ratings to screen COVID?

The recommendation is MERV 13 to remove some particles smaller than 1 micron (see table above).

42) I had a question about the ductless mini split ac units. The filtration is just a washable type. What would be a solution to get better filtration for these types of units?

I would check with the distributor and manufacturer to obtain the MERV rating on the washable filter and ask if there is a manufacturer supported MERV13 option. Some minisplit manufacturers do seem to offer "filter kits" for minisplits that you can add to the return air side. You can also consider portable air cleaners that have HEPA filters as an alternative way to provide filtration in classrooms.

43) If a school has an older HVAC unit(s) can they use a higher level of filtering then the unit was designed for?

I recommend discussing with the HVAC System manufacturer and testing the filters in the systems you are considering. Compare the "clean filter pressure drop" for MERV13 filters you are purchasing and buy filters with the lowest pressure drop possible. Test the MERV13 filter in your HVAC units by measuring the airflow with the new filters installed. Select a sample of HVAC units to retest airflow after a 1-2 months to ensure the systems are still performing well with the MERV13 filters.

44) MERV 13 filters will need to be changed MUCH more frequently than would MERV 8. When they are dirty, the fans will ride down their curves and provide lower flow to the building. Both of these points were not mentioned as concerns to changing to MERV 13 filters.

MERV13 filters have a much greater surface area than MERV8 filters and so, because of this, they can hold more contaminants by weight and so should have similar replacement intervals. Look at a MERV8 versus MERV13 filter side by side and you will see the MERV13 filter has many more pleats. Visualize if you open up the filter you will have much more surface area to hold all the dirt.

It is correct that if your systems have PSC motors that the airflow will drop as the filter loads. This should be accounted for in filter selection and filter replacement interval.

45) Do you have recommendations on HEPA filters?
Not specifically, but for portable filters consider the recommendations in slide 38.

HVAC Cleaning & Maintenance

46) Can you speak to the benefits of air conveyance system cleaning?

Mostly likely duct cleaning is not a high priority. It could have benefits if the ducts are so dirty that they are restricting airflow. A review titled ***Is ventilation duct cleaning (DC) useful? A review of the scientific evidence*** commented that: "[t]here is inadequate evidence to show that DC can improve airflow in ducts and reduce energy consumption. Although epidemiological studies indicate suggestive evidence that improperly maintained ducts are associated with higher risks of symptoms among building occupants, this review finds insufficient evidence that DC can alleviate occupant's symptoms."
Source: https://doi.org/10.1111/j.1600-0668.2010.00672.x

47) Cooling coils need to be cleaned and sanitized to remove biofouling of the coils, this needs to be mentioned.

This could have some benefits, particularly if the coil is so dirty that it's restricting airflow. This is an active area of research. A recent paper by Wu et al. (2016) discussed the potential concerns of bioaerosol depositing on cooling coil surfaces. Other concerns include: increased energy use due to the added thermal resistance with biofilms, re-aerosolization of deposited materials into the supply air, and possible degradation of the cooling coil surfaces shortening its useful life.
Source: https://doi.org/10.1016/j.atmosenv.2016.09.004

48) Are commissioning agents qualified to test and balance a system and ensure proper ventilation rates? Don't we really need qualified TAB technicians to be working on these systems?

Please see this whitepaper on qualified TAB technicians and how to locate one:
https://wcec.ucdavis.edu/wp-content/uploads/TAB-Technical-Report-051220.pdf

49) Is there a list for companies that would like to assist schools in executing on this guidance? Our firm has a network of HVAC contractors ready to execute on the ASHRAE ventilation guidance.

Please contact us by email to discuss this.

50) Excellent clear, concise information.

Thank you!

UV

51) A: What power densities would you need for UVC to be effective in the HVAC unit? (What air velocity will it work at?)
B: What about UVC lighting I. Ductwork?
C: What about UVC lighting in classroom ceilings for uno Cupid's times?
D: UVGI has been shown for decades to destroy surface and airborne microbes. Why would you downplay its effectiveness?
E: What is your take on uv lights in air handlers.
F: What are your thoughts on UV lights that can be added to HVAC systems

G: Has there been any reliable research on UV light or other installations in the duct work?
H: Wondering if there has been any reliable testing done on UV lighting or ionization in HVAC duct work to sanitize?

Please see this excellent document from ASHRAE on UVC, which includes a discussion of all applications:https://www.ashrae.org/file%20library/technical%20resources/covid-19/si_a19_ch62uvairandsurfacetreatment.pdf

To be clear, we are not trying to downplay its effectiveness, and instead stating that we think outdoor air rate and filtration are critical priorities before funds are spent on UVC systems. UVC in HVAC systems have limited exposure time to the air stream, which is described in the ASHRAE paper.

Bipolar Ionization

52) A: What are your thoughts on Plasma systems that can be added to HVAC systems

We think you are referring to plasmaair.com which appears to be a bi-polor ionization system. See more information below. Cold plasma is an emerging technology. It works by radicals (small reactive molecules) created by electric discharge that can oxidize and decompose chemical compounds in the air. There is very limited data available on their performance on virus deactivation.

B: Bi-polar ionization is a better product to kill viruses than UV.
C: Will you be discussing bipolar ionization to disinfect rooms
D: Do you have an opinion on ionization air cleaning systems such as AtmosAir
E: can you comment on effectiveness of bipolar ionization
F: Ionization systems often produce high levels of ozone that is a lung irritant and can trigger asthma so these should only be considered very carefully
G: Pros and cons of bipolar ionization?

ASHRAE guidance on using ionization as a technology to mitigate risk of COVID19 transmission: "Convincing scientifically-rigorous, peer-reviewed studies do not currently exist on this emerging technology; manufacturer data should be carefully considered." Aside from the efficacy of the technology, ionization has the potential to generate ozone. In California, all air cleaners must meet an ozone emission concentration limit of 0.050 parts per million to be certified. Besides ozone, ionization can also generate other irritants.
Source: https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-filtration_disinfection-c19-guidance.pdf
https://ww2.arb.ca.gov/our-work/programs/air-cleaners-ozone-products/california-certified-air-cleaning-devices

H: Are hydroxyl or ozone generating devices effective in reducing viable viruses indoors?

No. Do not use hydroxyl or ozone indoors. They are not effective. Hydroxyl, ozone, and their reactants are irritants that are harmful to human health.
Source: https://www.epa.gov/coronavirus/will-ozone-generator-protect-me-and-my-family-covid-19

CO2

53) A: As an IH & public health 0fficer, I have had long held concerns about use of CO2 as ventilated surrogate for this basic reason- you need enough of a population density to make CO2 results meaningful. If in-duct units measure sparsely populated areas & shows low results, a false conclusion of that area can be made for when it becomes fully occupied. Conference rms- good example. Also, I frequently see consultants walking around with hand held CO2 meters in big open areas- CO2 results will be meaningless. I guess what I'm saying is we need to do a better job explaining how to use CO2 results. Maybe you can add a white paper about this!
B: Lists of CO@ sensors- please include discussion about calibration!

We are recommending installing CO2 sensors for **long term** monitoring in classrooms, which are generally highly occupied on a regular basis. We agree that consultants walking around with CO2 sensors in unoccupied spaces serves no purpose. Thank you for the suggestion to include calibration information in a list of CO2 sensor products.

54) Any ideas to maintain CO2 level at 1100 ppm indoors? I am based in South Florida and we have high humidity throughout the year. If we open the air dampers to bring in fresh air, it will also lead to bringing in humid air which will lead to surface mold accumulation. Based on this it is extremely difficult to maintain 1100 ppm indoors. Any other suggestions or ideas based on our geographical location in South Florida without causing the classrooms to mold over?

The cooling coil should be able to dehumidify the mixed return/outdoor air appropriately. There will be energy required for this dehumidification. If the dehumidification is not sufficient, check that your refrigeration system is working correctly. If there is still a problem, you may consider reducing the airflow rate over the cooling coil in cooling mode to increase the dehumidification rate.

CO2 monitoring will help to ensure that you are meeting the right balance between energy use/comfort/and indoor air quality.

Additional dehumidification strategies may be possible, such as dehumidification of outdoor air before it mixes with building return air.

55) Can you confirm that CO2 is heavier mole than O2? If so can you confirm that the height of the CO2 sensor matters in a build. What level were the sensors placed in the classroom study?

In the study the sensors were about 4 feet above the floor. CO2 actually mixes very well with ambient air so the location of the sensor is not critical. It's best to have it at least 5 feet away from an open door or window. In our research we found no consistent increase or decrease in CO2 concentrations with mounting height. We also recommend that CO2 sensors be installed at locations away from where occupants are likely to sit or stand, to avoid the exhaled breath from occupants that can cause large fluctuations in CO2 readings.

56) I am interested in CO2 monitors if Theresa has more data on different brands, costs, etc.

We are working on compiling a list.

Natural Ventilation

57) Won't opening doors and windows while running equipment just push the outside air they are bring in through those openings?

Opening doors and windows will increase the overall amount of outside air brought into the room, even if the HVAC system is ventilating. The outdoor air supplied to the room quickly mixes with indoor air, such that any air exiting through windows/doors will be helping to exhaust indoor contaminants.

58) A: Will installing fans at each open door provide a good source of moving outdoor air through the room
B: Will running fans above each open door help to remove airborne contaminants out of a classroom and bring more fresh air in?

Strategically placed fans may help increase outdoor air rates. It is hard to say for sure how effective this will be because the results are dependent on a number of factors. Monitoring CO2 concentrations will provide an excellent source of data to determine how effective your ventilation strategy is. A well-ventilated classroom should have daily peak CO2 concentrations below 1,100 ppm.

59) In the case where the teacher opened both windows and the door in a portable classroom every day, has anyone calculated the added energy cost of doing this?

In the example we showed, the teacher that was vigilant about keeping windows and the door open achieved approximately the same level of ventilation that would have been provided by a properly designed, installed, and tested mechanical ventilation system. We are only recommending *at least* meeting the minimum level of ventilation recommended by ASHRAE in non-pandemic situations. This is a necessary use of energy. The cost associated with ventilation is highly dependent on climate.

60) does keeping the doors and windows open and allowing a wider control range affect the unit. ie freezing

No, I do not see a risk to the HVAC system. Energy costs may increase if ventilation rates are increased.

Webinar Video & Slides

61) A: will we be able to get copies of the slides?
B: Can I get a copy of this presentation? A copy of the video, I already have copy of the presentation.
C: Will this be recorded and will we get copy of slides?

Everything is on our website: https://wcec.ucdavis.edu/improving-indoor-air-quality-in-california-schools/

Other

62) The Johnson Controls email referenced a May 21 Certificate of Attendance. But today is May 28. Can guidance be provided on that?

We suggest you follow-up with Johnson Controls. Thanks.

63) A: Will we be able to get CEU credit for attending this webinar?
B: Can we get credit for continuing education. AIA credit in particular

I'm sorry we are not offering CEU credits for the webinar. We appreciate your attendance and hope that it was helpful.