ACTS FACTS

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VENTILATION IN PUBLIC SCHOOLS

Editorial – Monona Rossol

All over the country, school reopening plans are in the news. Administrators often are defending school's facilities and ventilation, and teachers are not convinced it is safe to go back. After reading a few of the engineers' ventilation reports here in New York City, it is clear what is wrong. The schools defend by showing they comply with the state-mandated ventilation standards. They don't see that these standards are ineffective against COVID-19. This article will explain.

ASHRAE. This acronym stands for the American Society for Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). They set standards for design, maintenance, and testing ventilation systems. They have been adopted by the state for the schools. The most relevant standard in this discussion is ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality.

THE PURPOSE. The ASHRAE 62.1 standard's purpose is stated as follows:

> 1.1 The purpose of this standard is to specify minimum ventilation rates and other measures intended to provide indoor air quality (IAQ) that is acceptable to human occupants and that minimizes adverse health effects.

"Acceptable to human occupants" means providing air that does not result in a significant number of complaints, and "minimizes adverse health effects" means measurable adverse effects in occupants that are related to the poor quality of the air. Unstated in this purpose, but equally important in practice, is saving energy. This puts the emphasis on "minimum" fresh (outside) air to reduce heating and cooling costs and save the building owner or operator money as well.

ASHRAE 62.1 heating and air-conditioning (HVAC) systems accomplishes this by drawing a small amount of air from outside of a building into the system and adding it to a much larger amount of recirculated air. Recirculated air is air that has been removed from rooms throughout the building through ducts and returned to the HVAC air handler to be mixed with that small amount of outdoor air. The amount of fresh air is usually under 20%.

Next this air mixture is adjusted for temperature and humidity, and run through a particulate filter and returned to those same rooms in the building. This cycle is constantly repeated. The speed at which these cycles occur is usually quantified in air changes per hour (ACH)

AIR CHANGES PER HOUR (ACH). The ceiling of most rooms with this kinds of ventilation systems have circular or square "diffusers" where this mixture of recirculated air and fresh air comes into the room. And in some other locations, usually also in the ceiling, there are grilles or slots through which the room air is returned to the air handler to go through another recirculating cycle.

When the volume of air coming through the diffuser equals the volume of air in the room, one air exchange has been achieved. This does not mean all the air in the room has been replaced because the air flows slowly into the room through the diffuser and mixes with the air in the room.

In other words, it takes many air changes in order to completely replace the air in a room. And the rate at which these air changes are delivered is measured in air changes per hour (ACH). If you do the math you will also see that the closer you approach 100% replacement, the longer it takes to remove those last amounts of remaining air. And theoretically, you never remove every last molecule. This phenomena is reflected in Table 1 which shows the time it takes to get from 99% to 99.9% complete replacement. For this reason, is it easier to use the 99% figure for replacement.

Diffuser

TABLE 1 - ACH EFFICIENCY

ACH	Time (mins.) required for 99% replacement	Time (mins.) required for 99.9% efficiency
2	138	207
4	69	104
6	46	69
8	35	52
10	28	41
12	23	35
15	18	28
20	14	21
50	6	8

THE FILTERS. The ASHRAE rating for filters is the Minimum Efficiency Reporting Values, or MERVs. And while they were originally developed to control what ASHRAE deemed as ordinary dust, today we have empirical data on the capture efficiency of these filters at various particle sizes.

Only 16 MERV filters categories were developed originally by ASHRAE. But since even better filters were needed, the standards for high efficiency particulate filters (HEPA) were adopted by ASHRAE for the MERV 17 to MERV 20 filters. These capture essentially all very small particles such as those from some manufacturers' "clean rooms" and the particles of COVID-19.

THE VIRUS. The COVID-19 virus particles are emitted with the liquid droplets created when we sneeze, cough, sing, talk, and even just breath through our noses. The large visible mist and droplets settle to surfaces quickly and are unlikely ever to get drawn up into the ventilation system. But the smaller ones, especially those that are under 10 microns can float in the air for long periods of time.

The longer these tiny droplets remain in the air, the more of the water in them evaporates leaving only mucous and other secretions from our lungs plus the virus itself (which is 0.125 microns in diameter). These dehydrated particles of virus and dry secretions can be in the range of 0.3 to 1.0 microns. Some of these particles have been documented to have remained airborne for many hours. One study's tests showed the particles were are still capable of infecting people after 16 hours.*

FILTERS FOR COVID-19. There is evidence from one study in which the virus has been detected on the through-side of a MERV 15 in both air handlers in a hospital** plus a number of cases of viral transmission that can only be easily explained by ventilation system transmission.

But that evidence is almost surely to be confirmed since it is clear that it is airborne, survives many hours, and is small enough to go through many types of filters and HVAC systems.

TABLE 2 - MERV FILTER PARAMETERS

MERV #	0.1 - 0.3µ*	1.0 - 3.0µ*
9	n/a	35%
10	n/a	50%
11	20%	65%
12	35%	80%
13	50%	85%
14	75%	90%
15	85%	90%
16	95%	95%
17 (HEPA)	99.97%	~100%

*µ = micron

Most schools use MERV 7 to 10 Filters. In addition, the percentage of fresh air added at at each cycle is under 20 percent.

If this is true, the following are both facts:

1. The system meets ASHRAE 62.1 and is compliant with the regulations

2. The system cannot protect occupants from exposure to the virus, even if they all wear masks and keep six feet apart.

HOW VIRUS EXPOSURE OCCURS. The reason an ASHRAE-compliant ventilation system can no longer be considered safe for occupants is that the ASHRAE standard is totally inappropriate for controlling a tiny particle generated in the rooms by the occupants. This tiny particle is airborne for hours and can travel on air currents all through the room. If the HVAC system provides the typical two ACH, the air is only replaced 99 percent after over two hours. And if the filter is not a MERV 17, the virus could be recirculated back into rooms in the building.

DISTANCING AND CLOTH MASKS. Only the large droplets are likely to settle within six feet. The tiny aerosol particles float on air currents all over the room and around barriers and shields. The N95 masks can capture 95 percent of these tiny particles, but teachers and students wear cloth masks that are only meant to stop the large droplets expelled by the person wearing the mask.

PERCENTAGE OF FRESH AIR. The last piece of this puzzle is the percentage of fresh air added on each cycle. Many HVAC systems provide 10 to 20 percent fresh air. This is too low to sufficiently dilute the virus particle in the air. Resetting the HVAC system's fresh air intake to 100 percent will provide a high level of protection but can raise heating and cooling costs unsustainably. Better strategies involve raising fresh air in tandem with better filters and more ACH.

WHAT DO THE TEACHERS NEED? The teachers and the parents of their students need three pieces of information to be provided by the school's engineering reports:

1. **Air exchanges per hour.**
2. **The grade of the filter in the air handling unit.**
3. **The percentage of fresh air introduced.**

With these three items available to them, they should be able to calculate a risk reduction estimate and provide teachers with the period of time it would take replace 99 percent of the air in classrooms. But in the meantime, I have thought of a way to give teachers a set point to make a seat-of-the-pants judgement on the efficacy of the system in their school.

AIHA PUBLICATION. AIHA published a guidance document called *Reducing the Risk of COVID-19 using Engineering Controls*, Version 1 on August 11, 2020. It includes a graphic on page four that plots risk reduction against ACH (the data is below). But these calculations are for a system using a MERV 17 (HEPA) filter. This means that the percentage of fresh air is then only relevant to occupant comfort because both fresh and recirculated air will be virus-free.

TABLE 3

EFFECTIVE ENGINEERING CONTROLS

(for HVAC system with MERV 17(HEPA))

AIR CHANGES/HOUR and Other Methods	**RELATIVE RISK REDUCTION**
12 ACH	99.9 % *
10 "	99 % *
6 "	95 % *
4.5 "	90 %
3 "	78 %
1 "	40 %
Face covering for all occupants	10 %
Face covering for CoV positive	5 %
N95 respirators for occupants	90 %

* AIHA rates these as highly effective

It is important to note that face coverings for all occupants only provides an estimated 10% risk reduction. Distancing also is not very effective against the aerosol.

Note also that a significant risk reduction of 95 percent requires six ACH and a MERV 17 filter. This fact can function as a base line for teachers to consider. I work with theatrical unions and the MERV 17 and six ACH are also our primary recommendations. I suggest that teachers and their unions do the same.

Unfortunately, most schools' systems do not have HVAC fans powerful enough to push air through the high resistance of a MERV 17 filter. It may be necessary to downgrade to a MERV 13 that can only capture 50% of the particles of concern. Then with six ACH, around 50 percent fresh air may produce a similar risk reduction.

WARNING ABOUT AIR TESTING. ASHRAE 62.1 limits the amount of carbon dioxide (CO_2) to 700 parts per million above outdoor air levels. It is routine to test the air for CO_2 in order to establish that there is sufficient ACH to meet the ASHRAE standard. But since the source of the CO_2 is people's breath, this test is only valid during normal occupancy load. Obviously ALL rooms that are either empty or have a low occupancy due to distancing will pass the CO_2 test. Tests for particulate are equally useless since particulates are mostly from outside air. During this crisis, outdoor air is "good" air even if it contains pollution particles. We are safer outdoors than in.

MORE: ACTS has information also showing open windows, unit ventilators, ionizers, UV lights, and many other solutions also are not sufficient.

footnotes: *, ** citations available on request due to limited space

APOLOGY to my wonderful students who all graduated with honor from my 5-day Safety in Art and Theater Course at the end of August. I'll thank you in the next issue. This had to be done now.

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