Background and Calculation of Air Exchange Rates Indoors

Typically, buildings with exterior doors and windows closed are designed to have as little air leakage, or exchange of air with the outside, as possible. This is a sound principle of building design for energy efficiency, as it keeps the cost of heating and cooling down.

However, in this time of virus contagion, we are all looking for buildings that have a HIGH rate of exchange of air with the outside. The closer the inside air flow can be to the outside air, the more we know there is a good flow of outside air to and through the inside. Not good for energy efficiency, but good for air flow!

The purpose of doors and windows is to allow fresh air into the building (along with light and access for people). The gym at Mount Olive Ministries doesn't have any windows but it does have plenty of doors. **We'll be using them to adequately ventilate our rehearsal space.**

Indoor air flow can be measured with a carbon dioxide (CO2) monitor, which measures the level of carbon dioxide in an enclosed area. There is always some amount of CO2 in a space, and when we get people into that space, the levels go up because that's part of what we are exhaling when we breathe, talk, or sing.

The element in our singing that is the cause of concern is less the big droplets you may see spitting from someone's mouth, and more the tiny, aerosolized particles that you can't see. The bigger droplets tend to fall to the ground in a relatively short amount of time and space, while the aerosolized particles tend to float and linger in the air around us.

What we want to do is get those aerosol particles moving away from us and dissipating in the air as quickly and efficiently as possible. Masking helps keep some of them contained, but not all. For maximum protection of all singers, we need to know how quickly those aerosol particles dissipate, and when we need to "take a break" from singing, to allow them more time to dissipate.

The air exchange rate (Air Changes per Hour, or ACH) of a space can be calculated from the readings of a CO2 monitor. As stated before, most buildings are designed to have only 1 or less ACH, for energy conservation purposes. For mitigation of aerosols, however, we are looking for an ideal ACH of 5 or more; 3 to 4 is "acceptable."

What does that mean? An ACH of 5 means that the air "changes" in the space 5 times every hour. (This would be a pretty "breezy" room under normal conditions!)

We conducted the CO2 test of the gym at Mount Olive Ministries like this:

1. Measured the outdoor air, which was about 420 parts per million (ppm) of CO2.
2. Measured the indoor air when we arrived, with the room empty and all windows and doors closed; it was about 720 ppm.
3. Filled buckets with dry ice and poured warm water on them, to activate the dry ice. (Dry ice creates CO2 when released.)

4. Watched the CO_2 monitor as the numbers rose (indicating higher levels of CO_2 and lower levels of oxygen).
5. When we got to about 2000 ppm, we stopped. (Going too much higher might create uncomfortable levels of CO_2 in the room.)
6. Removed the dry ice and watched the CO_2 monitor as the numbers decreased. (This took a LONG time.)
7. When we got down to around 1000 ppm, we stopped that part of the test. (The CO_2 monitor was feeding data to the computer regularly.) The ACH rate was only .38, indicating a well-sealed room - less than 1 air change per hour.
8. We then refilled the buckets with dry ice and got the CO_2 levels up to around 2000 ppm again.
9. We turned on all the A/C units, with all doors still closed, and watched the CO_2 monitor as the numbers decreased (again, very slowly).
10. The ACH rate improved, but just a wee bit, to .67 ACH (still less than 1 air change per hour).
11. We then opened all 4 doors into the gym.
12. CO_2 levels plummeted! In a very short period of time, the CO_2 levels were around 850 ppm, very close to the beginning empty hall number. The ACH rate was 7.47! Well above the target of 5!!

Based on the time for each step and the levels of CO_2 perceived by the monitor, we could determine that, indeed, the gym was built to be relatively well sealed. Air conditioning helped move air around enough to keep it cool, but did not bring in any significant amount of outside air, and did not meet our requirements for singing. However, with all the doors open, the ACH rate greatly exceeded our target!

For optimum protection in such a space, we would have at least one of the three A/C units on (the one with the most vents), and at least 2 doors open at all times while rehearsing for a cross-breeze. We could sing for about 30-45 minutes and then take a 15 minute non-singing break to allow any remaining aerosols to dissipate.

We would also monitor CO_2 levels during the rehearsal. It is not the CO_2 level itself that is a concern, but rather the trend if it rises considerably. That would indicate that air is not circulating adequately, and we could either open another door or leave the room for a while.

We also tested one of the small breakout rooms in another part of the building, following the same procedure outlined above. This took WAY less time because the room was so small. With the A/C on and door closed, we had a 3.71 air exchange rate. However, observation of the other (larger) breakout rooms showed that their exhaust vents were larger and would probably allow significantly more air changes per hour. With the door open, the ACH was 7.16.

The beauty of having 4 well-sealed breakout rooms is that we can have 4 sections doing breakout sessions simultaneously, but only if the doors remain closed (for soundproofing). Therefore we will want to limit the time that we spend in breakout rooms to about 30 minutes before taking a break with doors open.