HVAC CONSIDERATIONS

ADDRESSING CURRENT SUGGESTIONS

REGARDING

COVID-19 VIRUS AIRBORNE TRANSMISSION

AND SUBSEQUENT NEGATIVE IMPACT ON

EFFORTS TO AVERT

CLIMATE CHANGE

NOTE: A CASE STUDY WAS SENT TO US SINCE WRITING THIS PAPER WHICH READS VIRUS AT A FAN SYSTEM. MUCH OF THE DATA POINTS WE NORMALLY REQUIRE TO ASSESS SYSTEM PERFORMANCE WAS MISSING FROM THE SLIDES FOR THAT STUDY.

FURTHER INVESTIGATION IS REQUIRED TO COMPARE THAT STUDY TO THE SEEMINGLY CONTRADICTORY STUDIES FROM THE ALBERTA HEALTH SERVICES REPORT.

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PREFACE

1) The seriousness of the current COVID-19 pandemic is understood by most people and we are united in accepting that we must address the threat.

2) Most people also understand the seriousness of Climate Change and we are united in accepting that we must address that threat. (page 1)

3) The HVAC suggestions via ASHRAE and REHVA alter the fan systems from mixed air to maximum fresh air, which can increase the systems' negative impact regarding Climate Change via increasing Green House Gas (GHG) emissions into the atmosphere by 700% in some cases. (page 2)

4) If the suggested improvement to MERV13+ filters will capture the total airborne COVID-19 virus, we may provide protection from the virus and not increase Climate Change. (page 2 & 4)

5) The assumption that the virus can travel from an infected person, through the occupied space and then through the route to the fan system in a remote fan room and back to the occupied space seems questionable when social distancing rules maintain the virus cannot travel more than two metres. (page 3, 6, 7 & 8)

6) A study is required that identifies the virus content in the HVAC air at the defined locations of the drawings on page three of this report. We have to know where the virus actually exists before logical solutions can be established.

7) ASHRAE and Dr. Stephanie Taylor present the fact that relative humidity levels between 40% RH and 60% RH are beneficial to human health and detrimental to viruses. REHVA does not support this claim. This relationship of humidity level is very important in COVID-19 considerations in that introducing larger amounts of cold outdoor air will reduce humidity levels in the occupied space, which will benefit viruses and negatively impact human health, if Dr. Taylor and ASHRAE are correct on this matter.

8) Persons assessing the HVAC situation regarding COVID-19 virus airborne characteristics must not lump all HVAC airflow into one category.

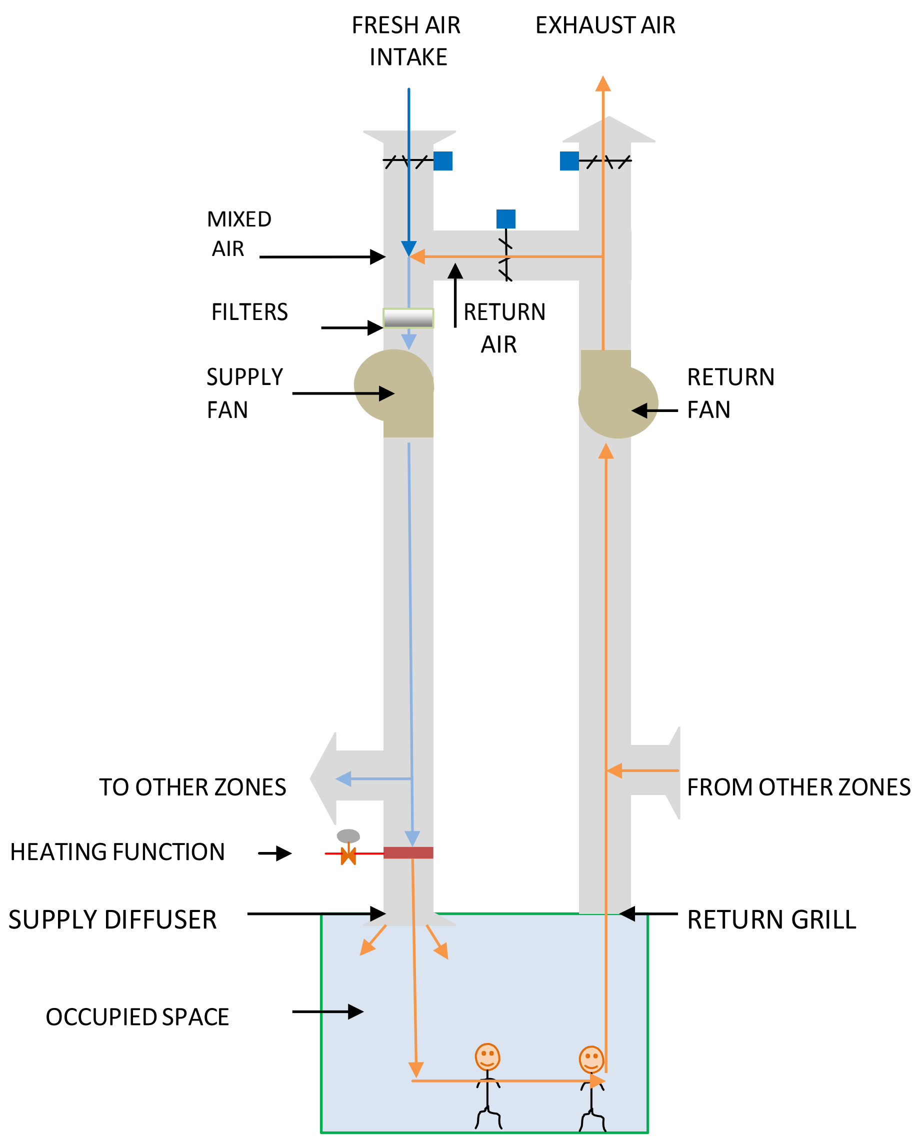
   They must separate the airflows into:

   a) Airflow from the supply fan to the point of entering the occupied space.

   b) Airflow through the occupied space.

   c) If the virus transmission is in the occupied space, while the supply fan's air is virus-free, no changes such as more fresh air or better filtration will improve the situation.

SIMPLE HVAC MIXED AIR SYSTEM



Pages iii, iv and v present my understanding of the new release from ASHRAE October 5, 2020

I'm interpreting Demand Control Ventilation (DCV) as variation of fresh air quantity from 0% to 100% based on minimum ventilation code, exhaust air replacement, occupied space CO_2 control or free cooling based on warmest zone requirements. ASHRAE may have a different definition.

On October 5, 2020 ASHRAE posted a new sheet regarding "GUIDANCE FOR RE-OPENING BUILDINGS" with some significant changes from the previous HVAC re-opening advice of July 17, 2020 and August 20, 2020.

We have two very dangerous social challenges simultaneously occurring globally:

1) **The CVOID-19 virus threat**. The HVAC actions suggested via the major Engineering societies in Europe (REHVA) and North America (ASHRAE) will produce added Green House Gas emissions.
2) **Climate change.** Action required is to reduce Green house Gas emissions.

We should not needlessly feed one of these monsters while attempting to address the other.

Current scientific studies show that the virus cannot travel from infected persons in the occupied space to the remote HVAC fan system and back to the supply air diffusers in the occupied space. Scientific studies are required to quantify the virus content at HVAC locations identified at the locations A, B, C, D, E and F on page three of this report. Social distancing rules imply the virus cannot travel more than two metres to infect another person. The net result of these facts is the supply air entering the occupied space cannot contain virus whether it contains fully fresh air or fully recirculated air. With no added virus protection benefit, the system altered to full fresh air may require over 700% more heat (page 2) to keep the occupied space warm. This will produce 700% more GHG emissions, which will tend to escalate Climate Change.

Often statements for better ventilation are voiced. The ventilation air from the supply fans must be considered from two different positions:

1) The air from the fan to the entrance point of the occupied space.
2) The air as it passes through the occupied space.

If the issue is with virus being passed from an infected person to another within the occupied space, the problem will still exist even if the supply air to that space is completely virus-free fresh air. Current scientific studies and the virus travel distance defined by social distancing indicate that the supply air to the space must be virus-free. Altering fresh air rate and filters at the HVAC fan is pointless when the supply air is virus-free before and after the HVAC alterations. If the problem is only in the occupied space, it must be solved in the occupied space. We should avoid the addition of pointless GHG emissions to the atmosphere.

The shift in operational changes via ASHRAE in the new positions posted October 5, 2020 must be conveyed very clearly to officials in school boards, government and teacher unions on ASHRAE's altered opinion regarding maximum fresh air in ventilation. The understanding should be conveyed that the supply air to the rooms would be virus-free before or after the original guidelines and the GHG emissions addition can be avoided if the systems are allowed to control under energy conservation logic that existed prior to the COVID-19 issue. Facility staff will not likely alter the public and teacher unions' opinion for maximum fresh air without very clear and public support of ASHRAE indicating the new position will not negatively impact the effort to correct the COVID-19 fight, but will prevent further damage to the planet via unnecessary GHG emissions.

<u>The comparisons of earlier ASHRAE guidance to the October 5, 2020 ASHRAE guidance are:</u>

1) August 20, 2020 "Ventilation: A good supply of outside air, in accordance with ASHRAE Standard 62.1-2019, to dilute indoor contaminants is a first line of defense against aerosol transmission of SARS-CoV-2. Pre- and post-occupancy purge cycles are recommended to flush the building with clean air."

   October 5, 2020: "Pre- or Post-Occupancy Flush with Outdoor Air: Focus on removing bio-burden pre-or post-occupancy of the building. Flush building for a time required to achieve three air changes of outdoor air (or equivalent, including effect of outdoor air, particulate filtration, and air cleaners)."
   Red highlighting added.

2) July 22, 2020: "During the Pandemic, disable any Demand Control Ventilation (DCV) and introduce the maximum possible OA flow 24/7 until further notice (including DOAS)."

   October 5, 2020" "Energy Savings: During Evaluation and Inspection, determine optimized control strategies that can be implemented per ASHRAE Guideline 36-2018, High-Performance Sequences of Operation for HVAC Systems."

   October 5, 2020: "Modes of Operation for the Building: Operate in Occupied Mode when people are present in the building, including times when the building is occupied by a small fraction of its allowable capacity."

3) October 5, 2020: "Ventilation and Filtration: Confirm systems provide required minimum amounts of outdoor air for ventilation and that the filters are MERV 13 or better filters for recirculated air. Combine the effects of outdoor air, filtration, and air cleaners to exceed combined requirements of minimum ventilation and MERV-13 filters.

The environmental benefits in the apparent shift are:

1) From two purge cycles a day to one is a 50% reduction in additional pollution generated.

2) The shift from disabling the Demand Control Ventilation to maintaining energy conservation logic is a potential 700% improvement in pollution reduction on some fan systems.

3) The shift from running fans 24/7 on maximum fresh air to operate in Occupied Mode when people are present in the building is the greatest reduction in additional pollution generation.

The initial opinion of the public may over-look or refuse to accept these three alterations. This would be environmental devastation regarding GHG emissions if we produce unnecessary GHG emissions. I believe a path must be found to scientifically quantify the virus content in the supply air of mixed air systems in 100% recirculation, with virus present in the occupied space. (Worst case scenario) The two case studies in the Alberta Health Report and the social distancing rule of two metres suggest the virus cannot travel through the fan system and back to the occupied space, but real data in virus content of the supply air is required to confirm this.

Demand Ventilation Control (DVC) based on temperatures only, allows the code requirement of minimum fresh air (example 20% fresh air) until the warmest zone has closed its heating device and requires cooling. The remaining 80% of the mixed air volume is increased in fresh air beyond the minimum just enough to satisfy the cooling requirement of the warmest zone. The variable cooling demand is limited to a minimum temperature of 55˚F (13˚C).

DVC may also vary the minimum fresh air quantity based on CO_2 levels in the occupied space.

The requirement to alter back to (DVC) is urgent now in that:

1) Many systems with DVC have been altered from variable mixed air temperatures to provide constant mixed air temperature at 55˚F (13˚C).

2) The day time outdoor air temperatures during spring and fall will cause the fans to be on about 100% outdoor air most of the time.

3) This causes a 15F˚ (8.3C˚) ΔT heating demand to warm the room to 70˚F (21˚C).

4) If the DVC is re-instated the mixed air temperature would vary automatically adjusting to 67˚F (19.4˚C) with outdoor air temperature at 55˚F (13˚C) and 20% minimum fresh air if the warmest zone required no cooling.

5) DVC control on minimum ventilation would require a 3F˚ (1.7C˚) ΔT to rise to the 70˚F (21˚C) room temperature rather than the altered circuit's 15F˚ (8.3C˚) ΔT. This is a 500% increase in heating required with the altered circuit.

6) During many spring and fall days the school's boiler with DVC can be run for a couple of hours in the morning to take the chill off the building and then shut down for the remaining day. The altered circuit with a 55˚F (13˚C) mixed would require the boiler to run all day compensating for the unnecessary cooling.

A study identifying virus concentrations at various locations in the HVAC system is required immediately. If that study contradicts existing studies identifying maximum virus travel and the social distancing rule of two metres, then both positions have to be thoroughly analyzed.

If new studies indicate that the virus can travel from the occupied space, through the HVAC fan system and back to the occupied space, the provable fact of escalating Climate Change by increasing HVAC fresh air intake should be considered in the final plans.

ASHRAE's support to convey the information in their October 5, 2020 announcement to the public is imperative now as the maximum benefit of DVC occurs in the spring and fall of the year.

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The Guardian

This article is more than 8 months old

We have 12 years to limit climate change catastrophe, warns UN

Urgent changes needed to cut risk of extreme heat drought, floods and poverty, says IPCC

Overwhelmed by climate change? Here's what you can do.

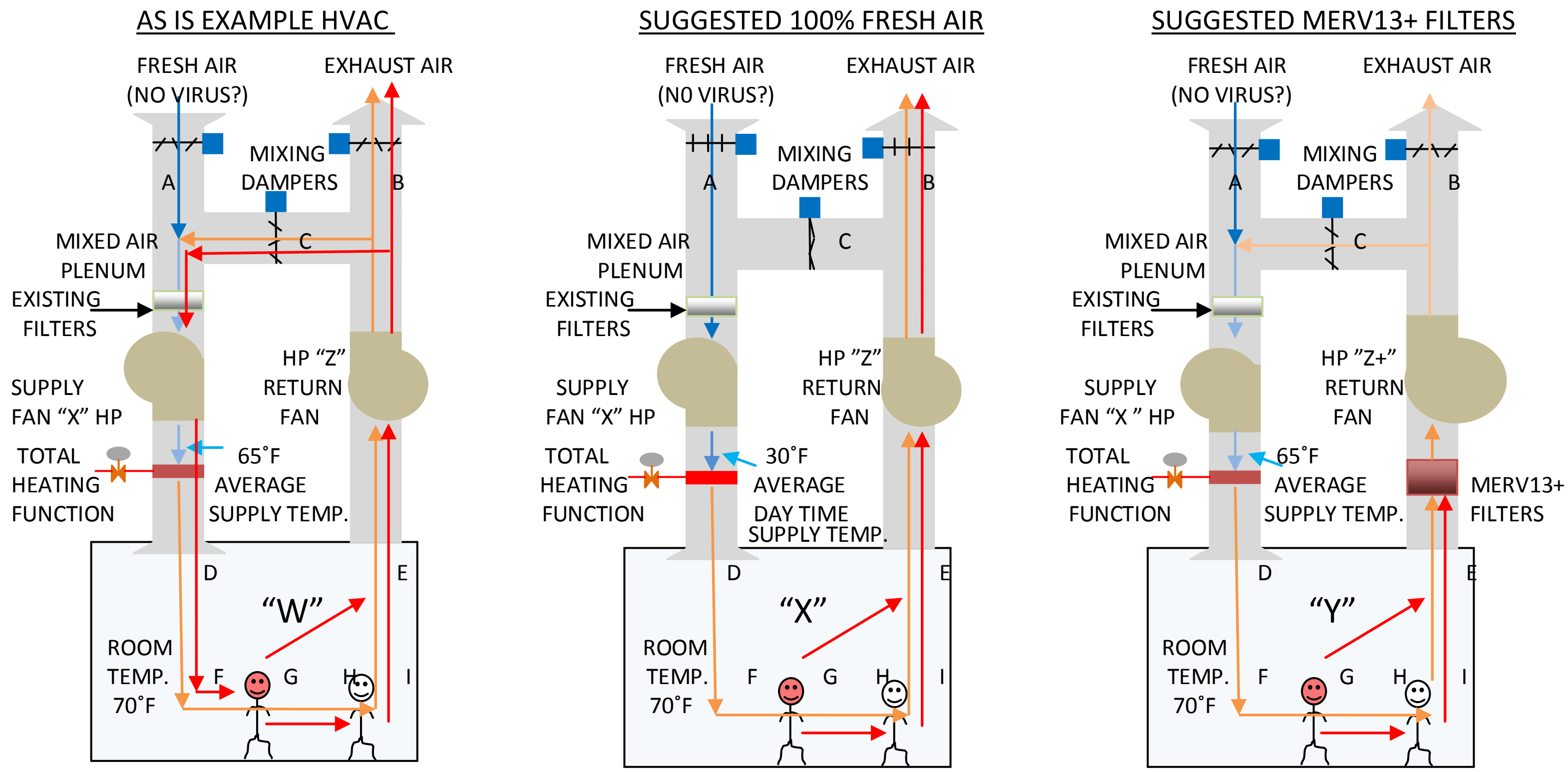
Jonathan: watts *Global environment editor*

Mon 8 Oct 2018 07.23 BST

The world's leading climate scientists have warned there is only a dozen years for global warming to be kept to a maximum of 1.SC, beyond which even half a degree will significantly worsen the risks of drought, floods, extreme heat and poverty for hundreds of millions of people.

The authors of the landmark report by the UN Intergovernmental Panel on Climate Change (IPCC) released on Monday say urgent and unprecedented changes are needed to reach the target, which they say is affordable and feasible although it lies at the most ambitious end of the Paris agreement pledge to keep temperatures between l.SC and 2C.

100% VENTILATION IMPACT ON CLIMATE CHANGE VIA INCREASED GREEN HOUSE GAS (GHG) EMISSIONS



NOTE: red arrows are virus travel range. All other arrows are HVAC airflow paths.

1) If the virus can be recirculated back to the occupied space as per example "W", positive correction is required; however, the impact on Climate Change, via increased Green House Gas (GHG), should also be considered.
   In example "W", the ΔT from the supply air temperature to the occupied space temperature is 5F˚ based on conservation logic's average mixed air demand temperature of 65˚F and an occupied space temperature of 70˚F.

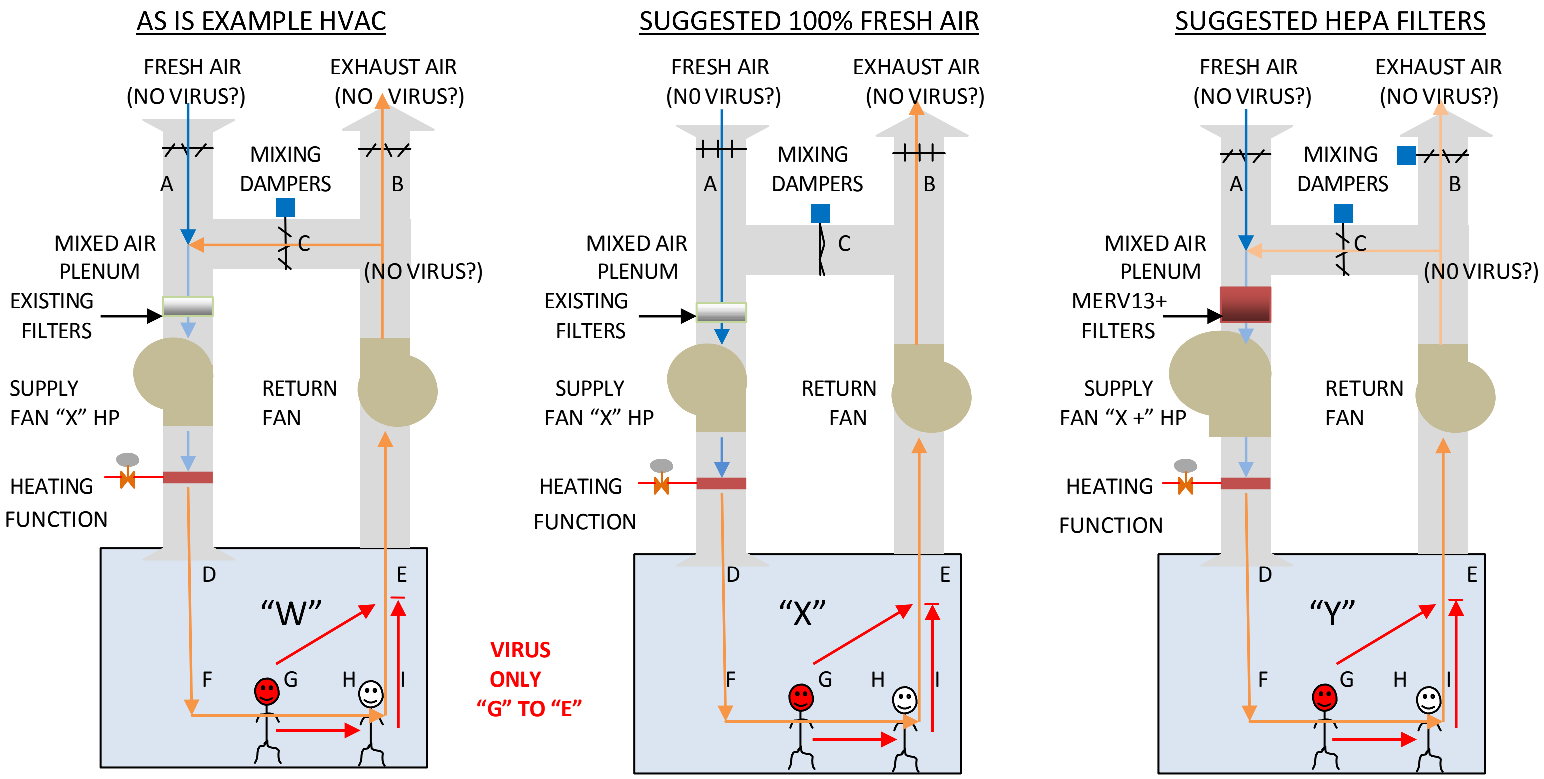
2) The supply air "D" may become virus free by altering the HVAC system to 100% fresh air as per example "X"; however, this action will cause a significant increase in GHG emissions.
   In example "X", the ΔT from the supply air temperature to the occupied space temperature is 40F˚ based on an average day time winter fresh air temperature of 30˚F and occupied space at 70˚F.

3) Altering from "W" to "X" illustrate a 700% increase in heating energy required at the HVAC system to maintain the occupied space at 70˚F. This will devastate operational budgets and increase the rate of Climate Change via increased GHG emissions. The design of most mixed air systems will not allow this operational change.

4) If the MERV13+ filters can completely capture the airborne viruses, example "Y" might be considered.
   The benefits are:
   a) The current energy conservation logic of "W" may be maintained; therefore, the 700% increase in energy use can be avoided, with no extra GHG emissions.
   b) If the virus is airborne over large distances, the exhaust in "Y" will be filtered to be virus free, removing the possibility of virus returning into the building via exhaust air short circuiting, via wind, into the supply air intakes.

   The down sides are:
   a) The return fan will consume more energy to overcome the pressure drop of the MERV13+ filters.
   b) If the supply air "D" is currently virus free, because the virus cannot travel from the occupied space to the mixing plenum; therefore, the supply air at "D" has absolutely no change in virus content from before to after the changes, the public may develop a false sense of safety and back off on other safety measures.
   c) This may actually cause COVID-19 infections to increase.

PRO'S AND CON'S OF CONSIDERATIONS FOR ALTERATION TO 100% FRESH AIR AND MERV13+ FILTERS



NOTE: red arrows are virus travel range. All other arrows are HVAC airflow paths.

According to case studies in the "COVID-19 Scientific Advisory Group Rapid Evidence Report, prepared for the Alberta Health Services, the virus can only travel up to 6m with wind speeds of 4km/h to 15km/h. (Alberta Health Services, Dbouk and Drikakis 2020 Page 7) and another case study states a maximum of 4m travel in patient rooms. (Alberta Health Services, Guo et al 2020 Page 6). Common knowledge accepts that the virus can travel no more than 2m, respecting social distancing. It seems unlikely the virus can travel from the occupied space to the mixed air plenum of the fan system.

As the supply air enters the room at "D", If it carries no virus, there is no virus contamination threat from that point to the person at "H".
As the air from "D" passes over the virus carrier person at "G", the air may pick up virus and carry it to the person at "H".
If "G" to "E" is more than 6m, current studies indicate that the air from "E" to "C" will contain no virus. Better filtration or more fresh air will not alter this outcome.

Altering from scenario "W" to "X" will provide no additional virus protection if the virus content is the same at "A" as it is at "B".
With no added virus protection, the system will consume much more energy, produce much more GHG emissions, have increased risk of freezing a coil, experience more low limit shut downs and will likely not be able to heat the space in severe winter weather.

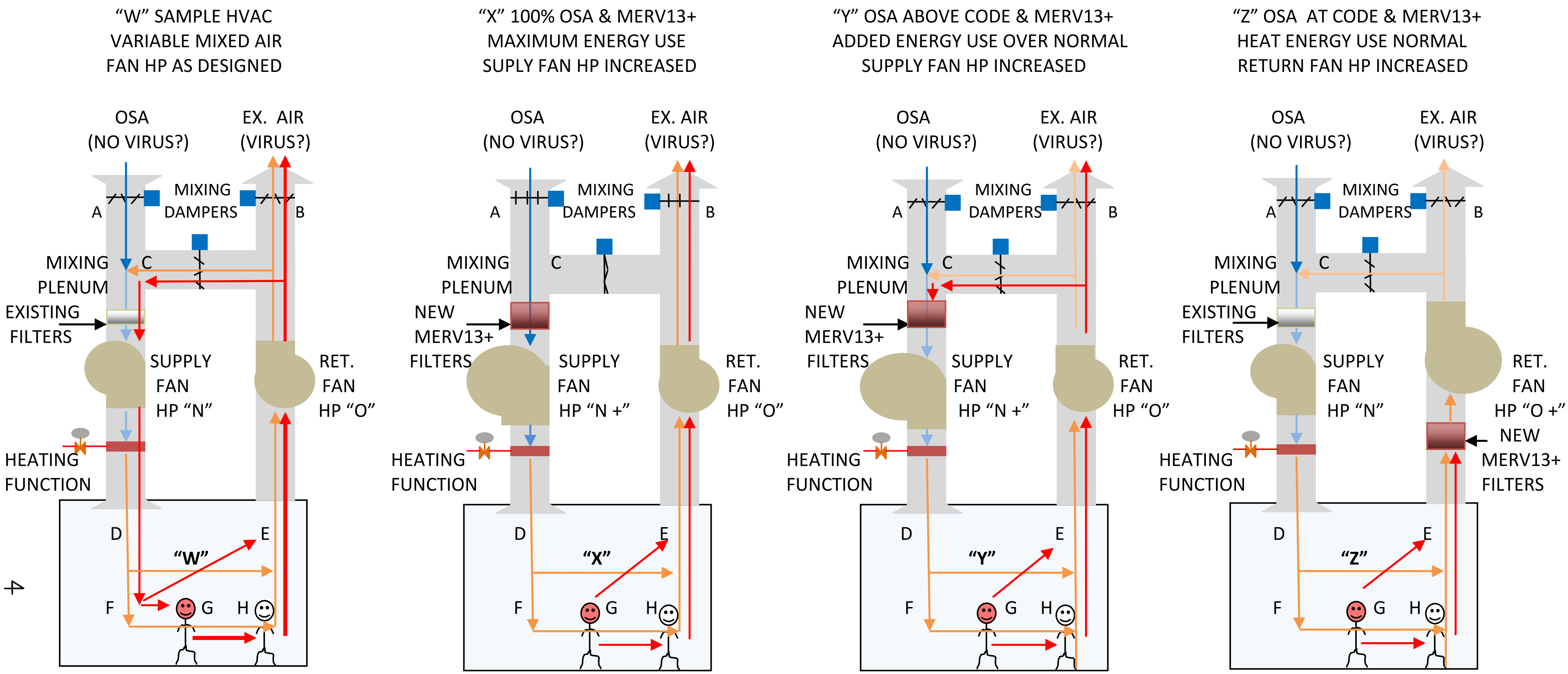
If MERV13+ filters are installed with scenario "X" and the virus content in the fresh air is considered to be virus-free, the virus content in the air before and after the MERV13+ filters will be equal, with no virus. The extra pressure drop of the MERV13+ filters over the existing filters will cause the fan's air volume to be decreased.

If MERV13+ filters are installed as per scenario "Y", the air entering the filters will likely be virus-free, as the fresh air at "A" and the return air "C" are likely both virus-free. The fan horse power will require increasing to produce the same airflow as scenario "W". With no added virus protection, the system will consume more energy and produce more GHG emissions.

We require a study identifying the virus presence at locations A, B, C, D, E and F. Current studies appear to assess the virus content from G to H. If the virus cannot travel from G to C, the alterations increasing the percentage of fresh air in the supply air at "D" and the change to MERV13+ filters will achieve nothing in addressing the virus transmission issue. Both changes will cost a lot of money that could be applied to other relevant solutions.

An additional concern is that excessive fresh air supply in cold weather tends to lower the relative humidity in the occupied space, benefitting the virus and is detrimental to the human occupants.

CONSIDERATION FOR MERV13+ FILTER INSTALLATION, IF THE VIRUS CAN TRAVEL FROM THE OCCUPIED SPACE TO THE HVAC MIXING PLENUM. CONSIDERING THE TIMING ISSUE, IT MAY BE WISE TO INSTALL MERV 13+ FILTERS, BUT STILL RESPECT CLIMATE CHANGE ENERGY CONCERNS.



NOTES: OSA-- (Outdoor Air), EX.-- (Exhaust air), RET..—(return), HP—(horse power)
RED arrows are suspected virus travel routes. Darker blue arrows are OSA. Lighter blue arrows are mixed air. Orange arrows are heated supply air.

CONSIDERATIONS:

1) The virus transmission issue must be solved with minimum negative impact on Climate Change via added GHG, considering extra energy requirements.
2) Virus airborne travel from G to H is likely based on case studies; however, I'm unaware of case studies proving virus travel from E to C. If A and C contain no virus, D will be virus-free, whether on 100% OSA or full recirculation. In this case the problem cannot be solved with alterations at the fan system, but in the occupied space.
3) If the virus can be recirculated as per example "W" and if the upgraded MERV13+ filters can capture the virus, Merv13+ filter installation should be considered.
4) Example "X" has MERV13+ filters, clean OSA and exhausts 100% at B. This will be extremely expensive, increasing Climate Change and most systems cannot do this in cold weather.
5) Example "Y" increases the OSA above current minimum ventilation code requirements and with no load analyzing logic has the same negative impact as "X", but not quite as severe.
6) Example "Y" could maintain current code levels and conservation logic if the virus can travel to C and the MERV13+ filters can remove the virus from the air.
7) Example "Z" MERV13+ filters capture the virus, preventing it from entering the mixing plenum, allowing HVAC conservation design to continue, supporting Climate Change reduction.
8) The MERV13+ filters have a greater pressure drop than existing filters; therefore, will require more fan power (more electricity) to maintain equal airflow as existing arrangements.
9) Increasing the OSA intake in cold weather will tend to reduce the indoor relative humidity, which benefits the virus and is detrimental to humans.
10) If the virus currently cannot travel from E to C, then D has always been virus-free. If the public believes that better filters and more OSA significantly solved the problem, when D is actually the same, the false sense of security may cause more careless activities in other protective measures. This could make our situation worse.
11) The MERV13+ filters, if required, may require new filter racks and spacing may be an issue in "Y", possibly making "Z" a more practical location for new MERV13+ filters.

COVID-19 Scientific Advisory Group
Rapid Evidence Report

Key Research Question:

Has there been documented transmission of SARS-CoV-2 virus (or similar viruses) through Heating, Ventilation, and Air Conditioning (HVAC) systems in hospitals or non-hospital settings?

Context

- Respiratory viruses are believed to transmit over multiple routes and the relative significance between aerosol and droplet transmission may vary among pathogens.
- The Public Health Agency of Canada (2020) and the World Health Organization (2020) consider the route of human-to-human transmission of SARS-CoV-2 to be predominantly via respiratory droplets or contact during close and unprotected contact, with a recommendation to use N95 respirators only in the context of aerosol-generating medical procedures.
- A reported outbreak of COVID-19 in an air-conditioned restaurant in Guangzhou, China that involved three family clusters was attributed to a longer range of droplet transmission, with the authors suggesting that was related to airflow generated by air conditioned ventilation but uncertainty over means of transmission remained.
- University of Alberta researchers have received research funding from the Canadian Institutes for Health Research to examine how SARS-CoV-2 may be transmitted through airborne fine particles, and how its movement is controlled by current HVAC designs in non-healthcare settings.
- There is concern about the possibility of promoting transmission of SARS-CoV-2 through HVAC systems inside and outside hospital settings.
- Evaluating the relative contribution of airborne versus droplet and contact transmission of SARS-CoV-2 is beyond the scope of this review. However, this review is presented under the working assumption that SARS-CoV-2 is primarily transmitted through respiratory droplets or contact and potentially short-range aerosols.
- Standards exist for the construction and maintenance of HVAC systems in healthcare and other settings, therefore recommendations for HVAC system design are beyond the scope of this review.

Key Messages from the Evidence Summary

- There is no clear evidence to date of transmission of SARS-CoV-2 associated with HVAC systems in hospitals or health care facilities, although there is a mechanistic possibility of this occurring. Studies that have identified the presence of viral RNA in procedure generated aerosols have not demonstrated viable virus that would be capable of infecting susceptible hosts, however viral culture may be relatively insensitive.
- There is epidemiologic evidence that HVAC conditions may have contributed to transmission of SARS-COV-2 in community settings including a restaurant, call centre and airplane, though in these events spread through close contact was not ruled out, and longer distance localized droplet spread related to airflow (given proximity to the index cases) is more likely than classic airborne transmission.
- The need to assess HVAC systems in the control of SARS-CoV-2 and other viruses is highlighted by various interim guidelines (Saran et al., 2020). Notably, rooms with higher air exchanges tend to have less viral RNA detected in the air, based on the literature identified.
- Given the complexity in the transmission modalities of SARS-CoV-2 and other similar viruses, lack of data on viable virus in air samples, and the wide variety of HVAC systems, studies have not been able to consider and evaluate all HVAC configurations and their potential to affect transmission of infection.

and isolation rooms in relation to spread of infectious diseases via the airborne route. Many of the epidemiological studies did not include adequate airflow studies (Y. Li et al., 2007).

Luongo et al. (2016) systematic review assessed epidemiologic studies published after 2000 and investigating the association of at least one HVAC-related parameter with an infectious disease-related outcome in buildings. The authors indicate that the data implies that HVAC system factors in buildings have a role in airborne pathogen transmission, but more robust, interventional studies are needed (Luongo et al., 2016).

SARS-CoV-2 & HVAC Systems in Healthcare Settings

Liu et al. (2020) investigated the aerodynamic nature of SARS-CoV-2 by measuring viral RNA in aerosols in different areas of two Wuhan hospitals during the COVID-19 outbreak in February and March 2020 (Liu et al., 2020). They collected thirty-five aerosol samples of three different types (total suspended particles, size-segregated, and deposition aerosol) in Patient Areas (PAA) and Medical Staff Areas (MSA) of Renmin Hospital of Wuhan University (Renmin) and Wuchang Fangcang Field Hospital (Fangcang), and Public Areas (PUA) in Wuhan, China during the outbreak. The ICU, CCU and general patient rooms inside Renmin, patient hall inside Fangcang had undetectable or low airborne SARS-CoV-2 concentration but deposition samples inside ICU and air sample in Fangcang patient mobile toilet room tested positive. The toilet room was a temporary single toilet room of approximately $1m^2$ in area without ventilation and had the highest viral load detected (19 copies/m^2). The airborne SARS-CoV-2 in Fangcang MSA had bimodal distribution with higher concentrations than those in Renmin during the outbreak but were negative after number of patients were reduced and rigorous sanitization was implemented. Public areas had undetectable airborne SARS-CoV-2 concentration but obviously increased with accumulating crowd flow. The authors interpreted this to suggest overall low risks in the well ventilated or open public venues. The authors also concluded that room ventilation, open space, proper use and disinfection of toilets can effectively limit aerosol transmission of SARS-CoV-2. For example, the negative pressure ventilation and high air exchange rate inside ICU, CCU and ward room of Renmin Hospital were effective in minimizing airborne SARS-CoV-2. The authors further concluded that transmission within crowds via airborne transmission is possible. The virus aerosol deposition on protective apparel or floor surface and their subsequent resuspension is a potential transmission pathway and effective sanitization is critical in minimizing aerosol transmission of SARS-CoV-2 (Liu et al., 2020).

Guo et al. (2020) tested surface and air (including air outlets) samples for SARS-CoV-2 using real-time PCR from an ICU and a general COVID-19 ward at Huoshenshan Hospital in Wuhan, China (Guo et al., 2020). Thirty-five percent (14/40) of the samples collected from the ICU and 12.5% (2/16) of the general ward samples were positive. Air outlet swab samples also yielded positive test results, with positive rates of 66.7% (8/12) of ICUs and 8.3% (1/12) for general wards. Rates of positivity differed by air sampling site with 44.4% (8/18) samples in patients' rooms, 35.7% (5/14) near air outlets and 12.5% (1/8) in the doctors' office area. The authors indicate that virus-laden aerosols were mainly concentrated near and downstream from the patients, with a maximum transmission distance of 4m. The air sampling sites in the general ward were distributed in different regions around the patient, under the air inlet, and in the patient corridor. Only air samples around the patient were positive. One of their conclusions was that SARS-CoV-2 was widely distributed in the air and on surfaces but did not associate this with HVAC systems (Guo et al., 2020). Both this and the Liu et al. (2020) study noted above are limited by the lack of viable virus testing. It is unclear whether environmental contamination with viral RNA contributes to clinical infection.

Ong et al. (2020) collected surface environmental samples at 26 sites from three airborne infection isolation rooms (12 air exchanges per hour) with anterooms and bathrooms in the dedicated SARS-CoV-2 outbreak center in Singapore between January 24 and February 4, 2020. Note: viral culture was not done to demonstrate viability. There was extensive environmental contamination by one SARS-CoV-2 patient with mild upper respiratory tract involvement. Toilet bowl and sink samples were positive, suggesting that viral shedding in stool[5] could be a potential route of transmission. Post-cleaning samples were negative, suggesting that current decontamination measures are sufficient. Air samples were negative despite the extent of environmental contamination. Two of the three swabs taken from the air exhaust outlets tested positive, suggesting that small virus-laden droplets may be displaced by airflows and deposited on equipment such as vents. The authors conclude the environment is a potential medium of transmission and supports the need for strict adherence to environmental and hand hygiene.

Buonanno et al. (2020) estimate the SARS-CoV-2 viral load emitted by a contagious subject on the basis of the viral load in the mouth, the type of respiratory activity (e.g. breathing, speaking), respiratory physiological parameters (e.g. inhalation rate), and activity level (e.g. resting, standing, light exercise). The authors conclude that the results obtained from the simulations highlight that a key role is played by proper ventilation in containment of the virus in indoor environments (Buonanno, Stabile, & Morawska, 2020).

Dbouk and Drikakis (2020) used computational multiphase fluid dynamics and heat transfer to investigate the transport, dispersion, and evaporation of saliva particles arising from a human cough (Dbouk & Drikakis, 2020). An ejection process of saliva droplets in air was applied to mimic the real event of a human cough. Their model took into account relative humidity, turbulent dispersion forces, droplet phase-change, evaporation, and breakup in addition to the droplet-droplet and droplet-air interactions. The authors further investigated the effect of wind speed on social distancing. For a mild human cough in air at 20 °C and 50% relative humidity, human saliva-disease-carrier droplets may travel up to unexpected considerable distances depending on the wind speed. When the wind speed was approximately zero, the saliva droplets did not travel 2 m, which is within the social distancing recommendations. However, at wind speeds varying from 4 km/h to 15 km/h, the saliva droplets can travel up to 6 m with a decrease in the concentration and liquid droplet size in the wind direction. The findings imply that considering the environmental conditions, the 2 m social distance may not be sufficient. Further research is required to quantify the influence of parameters such as the environment's relative humidity and temperature among others. The authors further highlight that further research is required to assess the probability of viral transmission and that a holistic approach to address these questions is needed. This would require closer interactions between individuals in medicine, biology, engineering fluid physics and social sciences.

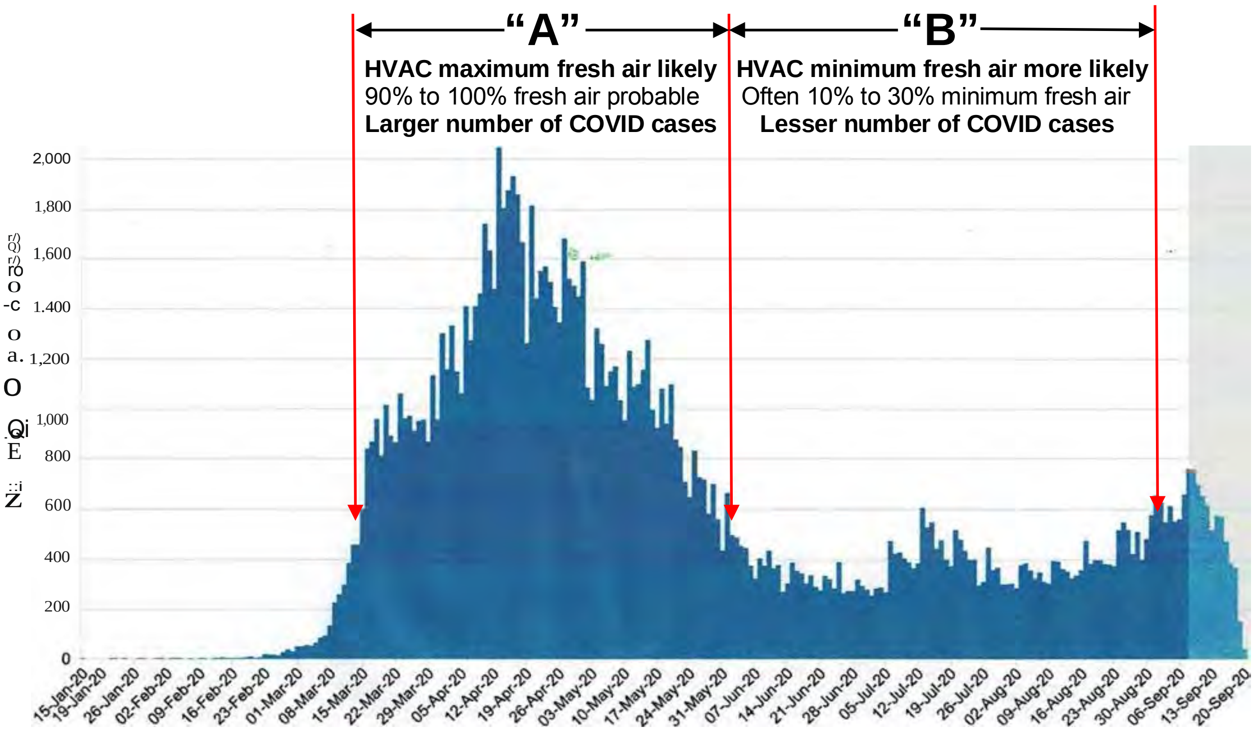
Morawska and Cao (2020) stated that based on the trend in the increase of infections, and understanding the basic science of viral infection spread, they strongly believe that the SARS-Cov-2 virus is likely to be spreading through the air and that it will take several months for this to be confirmed by science. The authors recommend all possible precautions against airborne transmission of SARS-CoV-2 virus in indoor scenarios be taken and that these precautions include increased ventilation rate, using natural ventilation, avoiding air recirculation, avoiding staying in another person's direct air flow, and minimizing the number of people sharing the same environment based on Qian & Zeng (2018). Morawska & Cao (2020) also recommend personal protective equipment, in particular masks and respirators should be recommended, to be used in public places where density of people is high and ventilation potentially inadequate, as they can protect against infection (by infected individuals) and infecting others (L. Morawska & Cao, 2020).

Other Viruses & HVAC Systems in Healthcare Settings

Li et al. (2004) presented a detailed air distribution study of a hospital ward during a major nosocomial outbreak of SARS-CoV in Hong Kong in March 2003 (Y. Li, Huang, Yu, Wong, & Qian, 2004). Retrospective on-site inspections and measurements of the ventilation design and air distribution system, three months after the outbreak, showed that the flow rates in the supply diffusers and exhaust grilles were not balanced. Measurements performed using bio-aerosol generator (with diameters between 0.1 and 10um) placed in one of the beds next to the index patient's bed (since it was occupied). At a height of 1.1m, concentration decreased as the virus laden bio-aerosols moved away from the index patient's cubicle. The concentrations at the doorstep of patient's toilet and store/clean room were relatively high – so risk if other patients in distant cubicles visited the toilets. Extraction fans in the store/cleaning room and in the patient's toilet seems to have also contributed to spread of bio-aerosols from index patient's cubicle to corridor and nurses station. Using their simulations and measurements, the predicted bio-aerosol concentration agreed with the spatial infection pattern which the authors indicated it suggested a probable airborne transmission route, in addition to the commonly accepted large droplet and close personal contact transmission (Y. Li et al., 2004).

Yu et al. (2005) conducted a retrospective cohort study of the SARS-CoV outbreak, noted above, on a hospital ward at the Prince of Wales Hospital, China (Yu, Wong, Chiu, Lee, & Li, 2005). Information on roles of healthcare workers and the ventilation system (location and size of supply diffusers, exhaust grills, supply air temperature, and the air-flow rate through each supply diffuser, exhaust grille and exhaust fan) were collected. Dispersion of hypothetical virus-laden aerosols, originated from the index case patient's bed, through the entire ward was

Normal fresh air ventilation trend in HVAC mixed air systems
Consideration of normal fresh air intake to COVID cases relationship



Canada's COVID infection graph. Date of illness onset

APRIL AVERAGE CANADA LOW/HIGH TEMPERATURES
Vancouver, BC: 44 / **56F**, (7 / 13C)
Edmonton, AB: 31 / **52F**, (-0 / 11C)
Winnipeg, MB: 32 / **51F**, (0 / 11C)
Ottawa, ON: 34 / **52F**, (1 / 11C)
Toronto, ON: 39 / **54F**, (4 / 9C)
Montréal, QC: 34 / **49F**, (1 / 9C)
Halifax, NS: 33 / **47F**, (0 / 8C)
St. John's, NF: 30 / **41F**, (-1 / 5C)
(Temperature values via tripsavvy)

MAY AVERAGE CANADA LOW/HIGH TEMPERATURES
Vancouver, BC: 49 / **63F**, (9 / 17C)
Edmonton, AB: 42 / **64F**, (6 / 18C)
Winnipeg, MB: 44 / **64F,** (7 / 18C)
Ottawa, ON: 47 / **67F**, (8 / 19C)
Toronto, ON: 50 / **66F**, (10 / 19C)
Montréal, QC: 46 / **63F**, (8 / 17C)
Halifax, NS: 42 / **58F**, (6 / 14C)
St. John's, NF: 36 / **51F**, (2 / 11C)

JUNE AVERAGE CANADA LOW/HIGH TEMPERATURES
Vancouver, BC: 54 / **67F**, (12 / 19C)
Edmonton, AB: 50 / **70F,** (10 / 21C)
Winnipeg, MB: 56 / **74F,** (13 / 23C)
Ottawa, ON: 56 / **75F**, (13 / 24C)
Toronto, ON: 59 / **76F**, (15 / 24C)
Montréal, QC: 58 / **75F**, (14 / 29C)
Halifax, NS: 51 / **67F**, (11 / 19C)
St. John's, NF: 43 / **60F**, (6 / 16C)

1) HVAC mixed air fans are more likely to maximize fresh air close to 100% in the seasonal range **"A"** because the outdoor air day time average temperature is close to the supply fans' normal low limit set point of 55˚F to 60˚F.
2) HVAC mixed air fans are more likely to minimize fresh air to design minimum fresh air quantities in the seasonal range **"B",** as the fresh air "free cooling" is often prevented, as determined by enthalpy comparison or dry bulb fresh air high limits via economiser logic. (Fresh air and return air enthalpies compared or fresh air over about 70˚F reverts fresh air quantity to minimum reducing mechanical cooling energy requirements.)
3) The current position that more fresh air will assist in the reduction of COVID-19 infections seems to be questionable given the infection rate and normal HVAC seasonal fresh air intake as graphed. Other factors seem dominant.
4) Most case studies focus on virus concentrations in the occupied space, but do not quantify virus concentrations in the airflow to and from the HVAC fans. Data is required showing virus concentrations in the occupied space, fresh air, return air as it enters the mixing plenum, in the exhaust air and the supply fans' discharge. This data is necessary in developing the most effective and most energy efficient plan.
5) It can be argued via some current case studies that there will be no gain in virus transmission reduction by flushing with 100% fresh air over mixed air, but 100% fresh air will increase operating costs and GHG emissions.

Graph source
https:llhealth-infobase .canada .ca/covid-19/epidemiological-summary-cov id-19-cases.html

SUMMARY

1) I suggest that in every organization an experienced HVAC engineer should oversee each total COVID-19 protection plan regarding HVAC alterations. Organizations employ people with varying types of expertise, however having a governing expert to provide oversight during this pandemic will ensure integration of knowledge, identification of gaps and overall success.

2) The effectiveness of the MERV13+ filters in capturing the COVID-19 virus should be verified. If 100% effective, return air filtration may allow conservation logic to remain, respecting the Climate Change threat.

3) A study assessing the virus content at HVAC locations presented on page three is required via a credible governing body. Understanding the locations of the virus is critical to establishing a safe plan.

4) The air from the supply fan must be viewed differently at two separate locations in the HVAC system. The airflow should first be considered from the supply fan to where it enters the occupied space and secondly as a different airflow as it passes over people in the occupied space. Completely virus-free air entering the occupied space can possibly pick up and transfer viruses between occupants in the space. Alterations to the supply air at the fan will be pointless if the air is already clean and the virus transfer is only within the occupied space.

5) If the virus cannot be in the return air at the entrance to the mixed air plenum by either return air filtration or the virus being incapable of travelling that far, allowing recirculation of air as per existing conservation logic should be considered respecting the Climate Change threat.

6) The impact of humidity levels between 40% RH and 60% RH on viruses and human health should be clarified. ASHRAE and REHVA have differing opinions. ASHRAE indicates between those RH values, viruses are less dangerous and humans' health is improved. If ASHRAE is correct, flushing with maximum quantities of cold fresh air is beneficial to the virus and detrimental to humans, because it will reduce relative humidity levels in the occupied space.

7) Information is changing on this issue as research is being reported. Everyone is putting their best effort into solving this common threat. Working as a positive team has value.

8) Questions, constructive criticism on any points or added information will be appreciated.

9) Acceptance and application of any concepts suggested in this report is the total responsibility of those designing, installing and commissioning the individual projects.