


FAIRFIELD PUBLIC SCHOOLS

Roger Sherman Elementary School, Roger Ludlowe Middle School, Fairfield Woods Middle School and Tomlinson Middle School

2020 Study of Ventilation Systems
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SECTION I

Typical Ventilation Rates

At the time of this report no studies have been performed that we are aware of that provide recommendations for new ventilation requirements for buildings in response to the COVID pandemic. Therefore, this report will examine the current requirements with respect to the code as well as the potential for existing systems to increase their ventilation rates beyond code requirements.

There are several different types of spaces which occur within schools. Low occupancy spaces include Offices, Administration Areas and Counseling Services. Medium density populated spaces would include Classrooms and Media Centers. High occupancy spaces include Auditoriums, Gymnasiums and Classrooms. Each type of space has requirements for ventilation rates based on their use. Ventilation rates discussed in this report are derived from the 2015 International Mechanical Code.

A typical classroom would be approximately 1000 square feet (sf) and have an occupancy of 25 students. Based on the requirements in the Code, a ventilation rate of 370 cubic feet per minute (cfm) of fresh air is required. Spaces such as Auditoriums and Gymnasiums end up having a much higher required ventilation rate since the HVAC systems serving these spaces tend to be designed for maximum occupancy. For example, a typical Gymnasium may be approximately 5,000 square feet for an elementary school with a typical classroom size of 25 students. This would warrant a ventilation rate of 370 cfm. However, a space like this is likely sized for an occupancy of as many as 500 students. For an occupancy of 500 students the Gymnasium would require 2,800 cfm of outside air. Therefore, large occupancy spaces within schools tend to have excess capacity for fresh air.

The code requires ventilation calculations based on how many occupants there are in a space, in addition to a required amount of fresh air per square foot of space. In terms of a ratio of airflow of fresh air (cfm) per square foot of occupiable space (sf) a space such as a Gymnasium would have approximately 0.06 cfm/sf. The required fresh air for a Gymnasium per person would be 5 cfm per person. Therefore, a typical elementary school Gymnasium would require approximately 250 cfm for the area requirement added to the 5 cfm per person for the occupant requirement.

SECTION II

Energy Recovery Ventilators

The State guidelines recommend bypassing energy recovery ventilators since they recirculate a portion of the exhaust air back to the supply air stream. We would recommend extreme caution before disabling any ERV's. It is very likely that the heating and cooling systems for a given air handling unit have been sized with the portion of recovered energy from the air transfer stream designed into the unit's capacity. This means that the absolute heating and cooling capacity of the units will be lower since the ERV provides a significant portion of makeup energy. If the ERV is disabled it is likely that the unit's heating and cooling capacities will be unable to maintain adequate temperature or relative humidity in the space(s).

SECTION III

Excessive Ventilation Rates

We do not recommend running any of the ventilation systems at 100% unless they are specifically designed for this. Introducing excessive fresh air in the summer will lead to humidity issues and the potential for mold formation and propagation. Introducing excessive fresh air in the winter may leave the building too cold and excessively dry if the heating systems do not have the capacity to handle this quantity of outside air.

The State recommends 'flushing' the building two (2) hours prior to occupancy and one (1) hour after occupancy with dampers open as fully as possible. Once again, if the systems do not have the capacity to handle this excessive ventilation there exists the possibility that there will be issues with maintaining space comfort or introducing excessive humidity to the building. Additionally, each school with a Building Management System (BMS) would need to be reprogrammed or have setpoints overridden to achieve this based on the occupancy schedule. If a given school does not have a BMS it would become difficult to keep up with manually adjusting damper positions on a twice-daily basis.

The guidelines also recommend running bathroom fans 24 hrs a day/7 days a week. The overall contribution to ventilation from bathrooms fans within a building is small however it may create a slight negative pressure such that air is being drawn into the building. As mentioned above, if the amount of air drawn in is excessive there may be humidity issues or temperature control issues if the building's ventilation system is unbalanced to a great extent.

Air Filtration

All HVAC system employ the use of air filtration. The ratings of these filters are indicated by their MERV rating (minimum efficiency reporting value). MERV ratings varying from MERV 4 to MERV 14 then on into the HEPA filtration range. The rating examines the size of the particle that it can trap as well as how effective it is in trapping that particle. The coronavirus is approximately 10 microns in size. A MERV 8 filter would be only 70% effective at trapping a 10-micron particle whereas a MERV 14 filter would have a 95% efficiency rating for trapping a similar particle.

Typical HVAC systems, depending on their style would have filters with a MERV rating between 10 and 12. Smaller air handling units do not have the capability of generating significant static pressure therefore they must use filters with lower MERV ratings. Large roof mounted air handling units likely can generate high static pressures and may be able to support increased levels of filtration. While increased filtration is a possibility each system must be examined to determine what the original design intent was with respect to filtration and how much room there is for increasing the MERV ratings. It must be noted that while increasing the HVAC system's filtration may trap 10-micron sized particles it also must not be considered as a method to stop the spread of the virus.

SECTION IV

Typical HVAC Systems

Gymnasiums, Auditoriums and Cafes

Spaces such as Gyms, Auditoriums and Cafes are designed with a high occupant load. As a result, they often have excess heating and cooling capacity when not fully occupied. For example, the Gym at Roger Sherman is designed for an occupant load resulting in an outside air requirement of 2800 cfm. This equates to roughly 500 people. On only rare occasions does the space see such large amounts of people. The unit has a design capacity such that, in theory, it could support a maximum of 3500 cfm. At 3500 cfm of fresh air the load would produce a ratio of 0.84 cfm/sf, 14 times greater than the fresh air requirement as prescribed in the code.

At Roger Sherman the large occupancy spaces were designed with the use of Demand Controlled Ventilation, or DCV. With this design the fresh air dampers remain closed until occupants enter the space and internal CO_2 levels rise. The fresh air dampers open to allow enough fresh air in to offset the increase in CO_2. In order to maintain a constant minimum ventilation rate, the DCV system would need to be overridden and the dampers set through the BMS to a predetermined position.

Without strict requirements as defined by the State, a best estimate based on unit capacity can be made for an increased ventilation rate which the unit's capacities can support. For air handling systems serving large occupiable spaces, what would be considered a very high ventilation rate would be 30% of the supply airflow of the air handling unit.

Classrooms

As mentioned above, a typical ventilation rate for a classroom would be approximately 375 cfm of fresh air. The amount that this may be increased depends on the systems serving the individual classrooms.

Roger Sherman Elementary School has three separate systems serving the classrooms. First, there is perimeter baseboard radiation providing heating in the winter months. Second, there is a heating and ventilating system which provides the code required fresh air. These units are gas fired and can temper the outside air. Third, there is a newly added VRV refrigerant-based, air conditioning system. The outside air does not directly connect to these systems. The capacities of each system must be looked at in order to determine an acceptable increase in outside air that the systems will be able to sustain. Based on the capacities of the systems it appears that the systems could handle an increase from 370 cfm to approximately 1000 cfm. A ventilation rate of 1000 cfm would imply an occupant load of almost 90 people within that given space, or 4 times the normal occupant load. Following the typical guideline of a 'large' ventilation rate of 30% a recommended fresh air intake of 520 cfm would be more appropriate.

VAV systems

A VAV, or variable air volume, system is one which utilizes a single air handling unit to serve multiple spaces and still provide individual space control. There is one heating and potentially one cooling coil at the unit as well as one outside air intake damper. Individual zone control is achieved using VAV boxes. VAV boxes provide control through the use of a damper which modulates airflow based on input from a thermostat within the individual space itself. Reheat coils are often provided to allow further zone control in the winter months. Large air handling units serving classrooms or office areas through the use of VAV boxes can only have their ventilation rates increased at the main outside air intake located at the unit. Though each unit has a maximum capacity for heating and cooling, which could result in an increased ventilation rate, there is no way to individually adjust or increase the ventilation to individual classrooms. At most, the ventilation rate would be supplied proportionally, based on the position of the VAV damper. As with large air handling systems, an increased flow rate to 30% of the supply fan rate would be considered a suitable increased amount of fresh air to the building while allowing the units to maintain space conditions.

Unit Ventilators

Unit ventilators which heat (and in some cases cool) classrooms, introduce fresh air through a louver mounted on the rear of the unit. These dampers are also very long and narrow. Typically, these dampers do not control the rate of ventilation very well. They are also very prone to early failure. Unit ventilators within schools should be examined and assessed by a qualified mechanical contractor to determine the condition of the outside air dampers and associated controls. Coils in unit ventilators generally do not have excess capacity and the amount of outside air introduced these units should be maintained to 25% of the total supply airflow or less.

SECTION V

Action Plan

Short Term Items

- Engage the services of a balancing contractor to ensure all outside air dampers are functioning properly and set to allow the original design ventilation rate. For units where the outside rate is unknown due to lack of information, set the minimum outside air position to 25%.
- Engage the services of a mechanical contractor to repair dampers, actuators, motors, etc. that the balancer finds to be in disrepair.
- Engage the services of a controls contractor to ensure the school's operating schedule is as intended and all units are functioning.
- The controls contractor would also set the building's occupied schedule to 24 hrs. per day in lieu of a full open fresh air purge. This would include overriding any systems operating with demand control ventilation (CO_2 control).

Long Term Items

- Retro-commission all heating, ventilating and air conditioning systems serving all schools.
- Engage the services of an architectural/engineering firm to perform load calculations and confirm design intent to determine required ventilation rates based on most current codes. Implement the findings with the help of a mechanical contractor, balancing contractor and controls contractor.
- Determine, if possible, the actual performance of the existing systems with respect to missing information including hot water, steam, chilled water and d/x refrigerant coil capacity.
- Determine, if possible, the extent to which existing systems can have their current filter ratings increased.

The most important recommendation at this time would be to engage the services of a mechanical contractor, controls contractor and balancing contractor to ensure that the outside dampers at all units are functioning. It is very common for dampers in HVAC systems to freeze or become non-operational over time.

The State guidelines recommend flushing the building for several hours a day, however we would recommend running the building in occupied mode 24 hours per day rather than introducing extreme amounts of fresh air in a very short amount of time.
For units with CO_2 demand control ventilation we would recommend overriding the DCV system in order to balance the airflow higher. DCV systems serving existing equipment can

also be bypassed and the airflow can be overridden to a predetermined minimum position guaranteeing fresh air is continuously being introduced to the zone.

SECTION VI

Discussion of State Issued Document “Guidance for School Systems for the Operation of Central and non-Central Ventilation Systems during the COVID-19 Pandemic“

This section will include a discussion and responses to the individual recommendations issued by the State in the above referenced document. Please refer to the Appendix section of this report for the State issued document.

Before School Opens:

‘Commission building mechanical systems for full occupancy (see details below for tips about how and why to commission mechanical systems for fall start-up). ‘

The services of a licensed engineer, mechanical contractor, controls contractor and/or balancing contractor should be obtained in order to determine the current operating condition of all mechanical equipment. As equipment ages dampers may fail, valves may stick and a variety of other issues with the system may occur. Each piece of equipment should be evaluated to ensure it is currently functional based on the original design intent.

‘Operate all ventilation systems at full capacity for one (1) week prior to the reopening of school buildings. ‘

All mechanical systems may be operated prior to the start of school however we recommend not running them greater than their intended design parameters. Issues may occur with overventilation of spaces with respect to temperature and humidity control.

‘Discuss with the entire facilities team and school administrators the general principles about what changes are planned to the usual ventilation system operation for the coming year. It will be important to communicate with school staff the importance of not making any adjustments to the mechanical systems inside school buildings (thermostats, fan speeds, etc.) without input from the facilities team. ‘

In addition to increasing communication between Facilities and Staff, building management systems, if present, should be modified based on what is determined to be the best operating schedule for each building.

After School Opens:

‘Flush the air inside the building for a minimum of two (2) hours prior to occupancy and one (1) hour after occupancy (after the night-shift custodians leave), with the dampers open as fully as possible (i.e. to maximize fresh air intake) during this flushing period. ‘

Rather than providing an extreme flush of the building we would recommend operating the buildings under their occupied schedules 24 hrs. per day. Systems may not have the capacity to deal with extreme levels of short-term ventilation air and humidity and temperature control problems could occur.

‘Program and lock fan schedules to align with the building occupancy schedule (i.e. provide flushing ventilation starting two (2) hours before building occupancy and one (1) hour post occupancy). ‘

Most buildings will already have some level of occupancy control. Buildings that do not will have to be manually controlled based on what is determined to be the most appropriate operating schedule. Engaging the services of a controls contractor to modify occupancy schedules will be required.

‘Develop a system for building users to notify the facilities department if the building needs to be open longer than usual so that the fan schedule can be altered for that day. ‘

The Staff will be required to communicate with the Facilities department such that the building occupancy schedule may be adjusted. Depending on the level of access each system has, a controls contractor may have to be engaged. As mentioned previously, running the buildings on a 24-hr. occupied schedule may be an effective way to ensure more effective ventilation air distribution. This would also result in eliminating the need for additional schedule adjustments.

‘Keep the ventilation system running during all hours that the building is occupied. ‘

The International Mechanical Code already requires that occupied buildings shall have their ventilation systems running while the building is occupied.

‘Do not allow teachers or other staff to make changes to ventilation system controls in their respective rooms. Explain to them the importance of keeping fans running all day. If temperature, noise, or other issues exist in certain areas, encourage staff to discuss the problem with the facilities department to try to identify a suitable fix that does not negatively impact ventilation.’

Increased communication will be essential in order to keep the occupants comfortable as well as the systems running to their desired effect. Additionally, buildings with BMS systems can be manipulated, in most cases, such that minimal levels of individual control can be provided to building occupants. For example, thermostats may be programmed such that a teacher in a given room may have the ability to adjust the temperature within a specified range such as 68F to 72F.

‘Keep bathroom exhaust systems running all day, every day (24 hours a day/7 days a week). ‘

Building ventilation systems need to run within their design parameters. Building exhaust systems can run continuously however conditioned, makeup air must be introduced to maintain the proper air balance and space comfort.

For isolation rooms to be used for holding sick students prior to dismissal, consider adding supplemental filtration, such as a portable air cleaner. This is particularly important if the ventilation serving those rooms cannot be run at 100% exhaust at all times. If a portable air cleaner is used, it should:

- *Contain HEPA filters only without ionizers, ozone generators, UV light, or other add-ons.*
- *Be correctly sized for the space, with an appropriate CADR (clean air delivery rate).*
- *Be located for greatest efficiency within the space. Be turned on at all times that the space is occupied.*

Increased filtration shows promise in trapping airborne particles. The higher the level of filtration, the smaller and greater number of particles may be trapped. It must be made clear that appropriate studies on how to handle the Covid-19 pandemic with respect to ventilation have not been performed and there is no definitive guidelines set forth for ventilation/filtration rates or whether supplemental methodologies such as UV light will be fully effective in managing the virus.

'Develop a specific plan for performing routine inspections and maintenance of mechanical systems, as specified in the commissioning process.'

The Facilities group will be required to work with the various contractors required to maintain system operability.

'For buildings without central ventilation systems or with certain areas not served by the central ventilation system, there are other important design considerations facility managers should be aware of, and in control of, in order to maximize available dilution ventilation and minimize the spread of virus particles inside their facilities.

- *At a minimum, where temperature allows and no other means of ventilation is available, windows should be opened to allow for some minimum level of fresh air exchange into occupied spaces.*
- *Window air conditioning units should be adjusted to maximize fresh air intake into the system. Air conditioner blower fans should be set on low speed and pointed away from room occupants to the extent possible.*
- *Ceiling fans should be adjusted so that fins are rotating in a direction that draws air up toward the ceiling rather than down onto occupants.*
- *Window fans should be turned to exhaust air out of the window in the direction of the outdoors. Ensure that fans are not blowing out of windows directly into walking paths or areas where individuals may congregate.*
- *Window fans that blow air into a room or free-standing fans that only serve to circulate existing air around a room should not be used.*

- *In addition, we do not recommend separate, free-standing air cleaner or HEPA filter units for individual classrooms. These units are highly variable in their effectiveness in larger open spaces such as classrooms and in general, any effect on indoor air quality is likely insignificant and greatly outweighed by the additional costs to school systems.'*

The recommendation to open windows fully is acceptable provided temperature and humidity may be sustained within the space. An overly humid space may lead to mold formation and propagation.

Adjusting the quantity of fresh air to any unit may be acceptable however the unit's cooling capability must be taken into account. If dampers on any system are opened past the unit's capabilities, temperature and humidity control will not likely be sustainable. Each unit must be evaluated to determine what its maximum allowable ventilation rate is.

While adjusting the direction to which air flows are possible, it must be noted that any air movement still has the capability to spread the virus. We are not aware of any studies showing this will be an effective strategy. Unless the air is directly exhausted it still will be recirculating the air within the space.

Adjusting window fans such that they are drawing air out of the space in theory may remove contaminated air, however that air will also be drawn from other parts of the building as makeup air. It is possible that air from other spaces may be drawn into a space that is exhausting air. If a given classroom has a source of makeup air and there is a window fan exhausting air from the space this may be an acceptable scenario. Another possible scenario would be to have two window fans, one which draws air in from the outside and one which exhausts air from the space.

Current research appears to be unclear as to the effectiveness of free standing filtration systems therefore this report would support the decision to not use them in the short term.

How to Commission Building Mechanical Systems for fall school reopening

'If your school system does not already have one that it routinely works with, hire a mechanical engineering firm with a proven track record in evaluating, adjusting, and balancing ventilation systems, particularly ventilation systems in school buildings, to commission all of the building's mechanical systems for full occupancy. The school facilities manager should be part of the discussion team talking with the engineering firm and the commissioning agent.'

Consider asking your Commissioning Agent the following questions:

- *How many and what types of systems serve your buildings, and which area of the building does each separate system serve?*
    - Refer to Section VII of this report.
- *What are the capabilities of the systems present in your school buildings?*
    - All systems were designed per the current Code at the time. The capabilities of each system will vary based on the use of the space. All spaces will be heated and ventilated. Some spaces will not have cooling. Refer to Section VII of this report for specifics.
- *Are the systems currently working to their full capabilities?*
    - Engaging the services of mechanical, controls and balancing contractors for a retro-commissioning process would ensure the operating condition of all existing equipment. Systems are rarely designed to run at full capacity at all times since they are designed in accordance with ASHRAE guidelines. A typical design summer temperature would be 87F and a typical winter design temperature would be 0F. Therefore the systems will vary their operating capacity based on the load.
- *Are the current systems' capabilities enough to satisfy full capacity for how the buildings need to operate now?*
    - Section VII provides theoretical ventilation rates for existing systems such that comfort control may not be impacted. In many cases it may be possible to increase ventilation rates and maintain space comfort however not all systems will be able to support this change. Increasing past these values would likely result in humidity and comfort issues.
- *Can demand-based systems be converted to constant volume until cooling season is over (if systems provide central cooling)? During heating season? Longer-term?*
    - Demand control ventilation can be suspended. This would require hiring a balancer and controls contractor in order to reprogram the building management system and to set the outside air rate of ventilation.
- *Can recirculation of air be suspended (economizers disabled)?*

  - Recirculation of air cannot be suspended as it is required to condition air. Economizers should not be disabled as economizers are designed to provide free cooling when conditions permit. This would also result in increased ventilation rates. We believe this comment may mean to disable energy recovery ventilators. This would not be recommended. Energy recovery ventilators recover a portion of the heating and cooling from the transfer between outside air and exhaust air. This is often factored into coil selection. If the ERV's were disabled it is very likely the heating and cooling capacities of the units would be reduced to the point where they would not be able to provide the necessary levels of heating and cooling.

- *Can they provide a summary of performance expectations for mechanical systems in the building?*
  - Generally speaking, the existing mechanical systems can perform based on the original design intent to which they were installed. All systems, if in working order, can be expected to perform to the ASHRAE standards to which they were designed for indoor temperature, outdoor temperature and rates of ventilation. As seen in Section VII there is the possibility that ventilation rates may be increased while sustaining building comfort. This will not be the case across the board for all systems. If new ventilation rates are proposed it is possible that some systems will be able to support these and others may need to be replaced.

As stated previously in this report, it is imperative that all systems be evaluated by a qualified team of individuals to determine that the systems are functioning according to their design. During the preparation of this report it was determined that not all of the information related to the existing equipment is available. Therefore, a further study will need to be performed to determine maximum rates of ventilation for each system. This may be performed in conjunction with a mechanical engineer, mechanical contractor, balancing contractor and controls contractor. These school's employ a variety of heating, air conditioning and ventilation systems. Large, packaged equipment often can support increased rates of ventilation while smaller split systems or unit ventilators may not. This means of in-situ evaluation also applies to determining to what extent the filtration may be increased in each system. Previously in this report (Section VI) a generalized summary of existing systems was presented with possible maximum ventilation rates. The rates presented are theoretical maximums however, it must be noted that no guidelines have been set forth at this point providing recommendations as to what the rates of ventilation should be. Therefore, when increasing rates of ventilation, the use of each space and the systems serving these spaces should carefully be evaluated.

The State Guidelines pose the question as to whether economizers can be disabled. We presume that the Guidelines are actually referring to energy recovery ventilators. Economizers are a series of dampers which allow the use of fresh air as a means of cooling when the outdoor conditions allow. Energy recovery wheels introduce fresh air to the system by transferring energy from the exhaust air stream to the fresh air stream. By doing this mixing of air does occur. Whether or not energy recovery wheels can be disabled must be evaluated for each system. Some systems were designed with heating and cooling coils which may support an operable scenario where the energy recovery wheel is effectively not running. Other systems appear to have been designed such that the heating and cooling coils have been downsized since the systems rely on the energy recovery aspect of the wheel to supplement the heating and cooling.

The Guidelines also pose the question as to whether demand-based systems be disabled. Demand control ventilation employs the use of carbon dioxide sensors to control the rate of ventilation to the space. If a space such as a Gymnasium were unoccupied there would be no CO_2 given off in the space and the damper would close. If the entire school entered the Gymnasium, CO_2 levels would increase, the sensor would detect this condition and the outside air damper would modulate open accordingly. These systems could be disabled by the controls contractor though a change in programming and the service of a balancer would be required.

'Include the following items in the commissioning process:

- *A complete set of measurements to understand total air distribution throughout the building.*
- *Inspection and evaluation of all building ventilation systems, both automated and manual.*
- *Air balancing and appropriate retesting to ensure parameters that satisfy the conditions of full occupancy of the buildings.'*
- *Inspections:*

- *Filter frames - Decide what kind of filter thickness and type you will be using if you decide to upgrade to a higher-rated filter. Discuss this with your ventilation engineering firm. Either way, all filter frames will need to be inspected. Replace or fix all bent, broken, misshapen frames to prevent air from by-passing the filter.*

- *Dampers and all associated controllers and actuators need to be visually inspected. Do not rely only on looking at a computer screen if you have an automated building system.*

- *Inspect, verify, and modify automated set points, if needed. Discuss both temperature and CO2 set points in newer buildings that utilize these variables for automated decision-making.*

- *Locations of supply and return diffusers. Look at ventilation effectiveness and whether short-circuiting is occurring. This happens frequently when supply and return diffusers are too close to each other. Discuss the possibility of moving them farther apart if this is occurring. If supplies and returns are ducted using flex duct and the room has a suspended ceiling, relocating can be performed more easily.*

Evaluations of the schools with respect to airflow have previously taken place. Balancing reports have been provided which indicate the most recent airflows to the various spaces. Most of these reports, however, are 15 years old or older. It is the recommendation of this report to reevaluate the existing systems using a mechanical engineer, a mechanical contractor, a controls contractor and a balancer to determine the current operating status, ventilation rates and future capacities of all of the systems within the schools.

All of the recommendations regarding the commissioning process are supported by the findings of this report. In evaluating mechanical systems, the following would be some of the parameters which may be noted:

- Total system airflow, including supply, return, exhaust and outside air.

- Airflow to individual spaces.

- Supply and return side static pressure.

- Duct traverse static pressures.

- Amperage settings from fan motors.

- Discharge, return and outside air temperatures.

- Damper settings.
- Coil sizes and data.
- Hot water, chilled water flow rates to each coil, as applicable.
- VAV damper settings.
- Current filter ratings.
- Supplemental controls such as demand control ventilation and economizer.

Strive toward the following ventilation goals.

- *Increase outdoor air ventilation as much as possible by disabling demand-controlled ventilation systems and opening outdoor air dampers to 100%, as indoor and outdoor conditions permit. Disabling demand-based systems will allow fans to run continuously.*
- *Tune ventilation systems to enable them to perform to the maximum capacity consistent with full occupancy conditions for the building.*
- *Bypass energy recovery ventilation systems that leak or recirculate potentially contaminated exhaust air back into the outdoor air supply.*
- *Once fans are running continuously, provide increased particle capture by increasing air filtering capacity through repair/upgrades to current system, where needed. This includes filter frames, filter configuration, and filter rating (ASHRAE recommends striving for filters with a MERV-13 rating where possible).*

Increases in system ventilation must be made carefully with consideration for the existing system's capability to support these increases with respect to maintaining building comfort. The employment of a qualified team of engineers and contractors will ensure that systems are operational or repaired as required to function as designed. Arbitrarily running systems with a 100% ventilation rate may not be in the best interest of the building as humidity and temperature controls issues may arise.

As stated previously, whether or not energy recovery ventilators can be bypassed will be determined on a case by case basis. If the system's heating and cooling coils were sized based on the energy recovery ventilators recovered energy capacity this may not be a possibility. Systems with oversized heating and cooling coils may be able to support bypassing the energy recovery wheels.

Increasing the system's filtration capability may be useful given that the data appears to support the conclusion that airborne particles may be trapped by increased filtration efficiencies. (Refer to chart provided on page 16 of this report.) Individual systems will need to be evaluated to determine to what extent filtration rates may be increased. There is a significant pressure drop associated with increasing filter efficiencies. This pressure drop results in lower total airflow unless the individual piece of air handling equipment has a large enough fan motor to support this.

SECTION VII

Estimated Ventilation Calculations

The following tables provide an estimate of suggested maximum outside air rates which may be delivered to individual units. In many cases it appears that the units have the ability to provide more outside air than is currently being provided. This may be due to coil capacity or the integration of an ERV. The last column in the charts indicates the suggested maximum outside rate. The maximum suggested rate may be less than what the unit has capacity for. It is the suggestion of this report that excessive rates be avoided in order to maintain space humidity and temperature levels, as well as maintaining a reasonable air balance within the buildings. Without specific guidelines provided by a comprehensive scientific research study by the State or Federal Government, the suggested rates, in most cases, present an increase in current ventilation rates without compromising the unit's performance.

In many cases the information regarding coil capacity was unavailable. Therefore, the suggested ventilation rates cannot be provided. In most cases, larger air handling equipment can support a ventilation rate of 25% to 30% of the total supply airflow. For smaller units such as fan coil units or unit ventilators, without being able to verify the exact capacity the recommendation is to keep the maximum amount of fresh air to 20% or below of the total supply fan rate.

Calculations

Roger Sherman Estimated Ventilation Calculations

Unit	Area	Supply Air	Outside Air (Design)	Summer Estimated OA	Winter Estimated OA	New Max OA
RTU-2	Gym	12,000	2,800	4,782	3,526	4,000
RTU-3	Café	5,000	730	2,292	2,506	1,650
RTU-4	Media Center	3,000	825	1,132	881	880
VRV/HV	Classrooms	1,341	390	1,182	1,851	410

(Approx 19 VRV/HV Systems)

Tomlinson Estimated Ventilation Calculations

Unit	Area	Supply Air	Outside Air (Design)	Summer Estimated OA	Winter Estimated OA	New Max OA
RTU-1	Classroom	17,000	6,200	11,145	7,332	6,200
RTU-2	Classroom	25,300	10,600	14,594	717,350	10,600
RTU-3	Classroom	18,050	6,300	11,386	8,511	6,300
RTU-5	Café	9,050	4,525	7,538	9,523	4,525
RTU-9	Auditorium	12,000	5,100	7,913	12,693	5,100
RTU-10	Locker Room	2,500	2,500		2,500	2,500

- **RTU's above have energy recovery wheels**

Unit	Area	Supply Air	Outside Air (Design)	Summer Estimated OA	Winter Estimated OA	New Max OA
RTU-4	Media Center	8,000	1,875	4,095	5,635	2,400
RTU-6	Class/Admin	7,700	3,000	5,031	5,620	3,000
RTU-7	Class/Admin	11,700	3,000	4,619	7,438	3,510
RTU-8	Aux Gym	4,500	1,800		2,409	1,800
AHU-11	Band	4,600	1,700	2,750		1,700
AHU-12	Kitchen	5,500	3,000		3,098	3,000

- **Blanks spaces indicate a lack of information regarding this system.**

Roger Ludlowe Middle School Estimated Ventilation Calculations

Unit	Area	Supply Air	Outside Air (Design)	Summer Estimated OA	Winter Estimated OA	New Max OA
AH-1	Band	18,000		11,167	3,635	3,635
AH-2	1st Classes	18,000		11,167	3,635	3,635
AH-3	2nd Classes	18,000		11,167	3,635	3,635
AH-4	1st Classes	18,000		11,167	3,635	3,635
AH-5	1st Classes	18,000		11,167	3,635	3,635
AH-6	1st Classes	18,000		11,167	3,635	3,635
AH-7	Upper Lobby	8,000		4,639	1,610	1,610
RTU-1A	1st Classes	21,000		13,028	4,244	4,244
RTU-1B	Cafe	19,000		11,625	3,830	3,830
RTU-1D	Auditorium	25,000		15,509	5,049	4,652
RTU-1I	Main Lobby	5,000		3,102	1,185	1,185
RTU-2A	2nd Classes	14,000		8,685	2,830	2,830
RTU-2B	2nd Classes	18,000		11,167	3,635	3,635
RTU-2C	2nd Library	10,000		6,204	2,012	2,012
RTU-3A	3rd Classes	12,000		7,444	2,415	2,415
RTU-3B	3rd Classes	12,000		7,444	2,415	2,415
RTU-3C	3rd Classes	17,000		10,546	3,440	3,440
RTU-1C	Kitchen	7,500	7,500	14,132	5,500	7,500
RTU-1E	Main Gym	30,000	30,000	56,528	29,198	30,000
RTU-1F	Aux Gym	9,000	30,000	16,950	8,756	9,000
RTU-1G	2nd Class	4,200	4,200	7,912	4,086	4,200
RTU-1H	Basement PE	4,000	4,000	7,545	3,891	4,000

- **Blanks spaces indicate a lack of information regarding this system.**
- **RTU-1-C, E, F, G, H are 100% outdoor air units.**

Fairfield Woods Middle School Estimated Ventilation Calculations

Unit	Area	Supply Air	Outside Air (Design)	Summer Estimated OA	Winter Estimated OA	New Max OA
RTU-1	Media	7,900	1,745			
RTU-2	Computer	3,200	570			
RTU-3	Computer	3,200	405			
RTU-4	Textile	2,000	360			
RTU-5	Cooking	4,000	460			
RTU-6	Admin	4,200	420			
RTU-7	Health	3,600	620			
RTU-8	Café	5,600	5,600	5600	5600	5600
RTU-9	Old Gym	8,400	2,610			
RTU-10	Music	10,290	2,780			
RTU-11	Gym	10,000	2,830			
RTU-12	Gym	10,000	2,830			
RTU-13	Fac Dining	1,500	320			
RTU-14	Auditorium	11,495				
RTU-15		2,700	800	1258	946	800
RTU-16	Science/Art	21,000	11,655	16,847	13,800	11,655
RTU-17	OT/PT	1,420	550	889	484	550
RTU-18	Aux Gym	2,520				
RTU-19	Class 202	1,120	390	714	364	390
RTU-20	Class 206	1,420	320	872	315	320
RTU-21	Key 152	1,120	390	714	364	390
RTU-22	Psych/Guide	1,120	390	714	364	390
ERU-1	Science	5,000	5,000			5,000
Unit Ventilators in Classrooms (Qty-50)			360			

- Blanks spaces indicate a lack of information regarding this system.

APPENDIX

FILTER EFFICIENCY BY MERV RATING

Excerpted from ‘Understanding Filter Ratings: MERV, FPR and MPR’, Allison Bailes, May 28, 2020, energyvanguard.com

	Minimum % of particles trapped		
	“PM 2.5 Zone”		
MERV Rating	0.3 - 1.0 Microns	1.0 - 3.0 Microns	3.0 - 10.0 Microns
MERV-16	>95%	>95%	>95%
MERV-15	>85%	>90%	>95%
MERV-14	>75%	>90%	>95%
MERV-13	>50%	>85%	>90%
MERV-12	>35%	>80%	>90%
MERV-11	>20%	>65%	>85%
MERV-10	-	>50%	>80%
MERV-9	-	>35%	>75%
MERV-8	-	>20%	>70%
MERV-7	-	-	>50%
MERV-6	-	-	>35%
MERV-5	-	-	>20%
MERV-4	-	-	<20%
MERV-3	-	-	<20%
MERV-2	-	-	<20%
MERV-1	-	-	<20%

Excerpt from the 2015 International Mechanical Code Indicating Required Ventilation Rates

TABLE 403.3.1.1
MINIMUM VENTILATION RATES

OCCUPANCY CLASSIFICATION	OCCUPANT DENSITY #/1000 FT^2 [a]	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_p CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_a CFM/FT^2 [a]	EXHAUST AIRFLOW RATE CFM/FT^2 [a]
Correctional facilities				
Booking/waiting	50	7.5	0.06	—
Cells				
without plumbing fixtures	25	5	0.12	—
with plumbing fixtures[g]	25	5	0.12	1.0
Day room	30	5	0.06	—
Dining halls (see food and beverage service)	—	—	—	—
Guard stations	15	5	0.06	—
Dry cleaners, laundries				
Coin-operated dry cleaner	20	15	—	—
Coin-operated laundries	20	7.5	0.06	—
Commercial dry cleaner	30	30	—	—
Commercial laundry	10	25	—	—
Storage, pick up	30	7.5	0.12	—
Education				
Art classroom[g]	20	10	0.18	0.7
Auditoriums	150	5	0.06	—
Classrooms (ages 5-8)	25	10	0.12	—
Classrooms (age 9 plus)	35	10	0.12	—
Computer lab	25	10	0.12	—
Corridors (see public spaces)	—	—	—	—
Day care (through age 4)	25	10	0.18	—
Lecture classroom	65	7.5	0.06	—
Lecture hall (fixed seats)	150	7.5	0.06	—
Locker/dressing rooms[g]	—	—	—	0.25
Media center	25	10	0.12	—
Multiuse assembly	100	7.5	0.06	—
Music/theater/dance	35	10	0.06	—
Science laboratories[g]	25	10	0.18	1.0
Smoking lounges[b]	70	60	—	—
Sports locker rooms[g]	—	—	—	0.5
Wood/metal shops[g]	20	10	0.18	0.5
Food and beverage service				

STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH

Deidre S. Gifford, MD, MPH
Acting Commissioner

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Guidance for School Systems for the Operation of Central and non-Central Ventilation Systems during the COVID-19 Pandemic

Improving ventilation in school buildings is just one part of system of procedures that will safeguard the health and safety of students, teachers, and school staff during the COVID-19 pandemic. Other parts of this system of procedures include physical distancing, face coverings, and efficient identification and isolation of sick students and staff. While improving ventilation is not necessarily the most effective tool for reducing transmission of the virus that causes COVID-19 (maintaining social distancing and wearing face coverings are far more effective), some studies suggest that adjustments and attention to proper ventilation can reduce the viable virus load in indoor spaces. In addition, we know that providing good ventilation in schools is important even outside of the COVID-19 pandemic, because it has been shown to improve student and staff performance in educational settings.

This guidance provides actions schools should take to ensure that their ventilation systems are performing optimally. The goal is not for schools to invest in costly upgrades and add-ons to existing mechanical systems. Rather, schools should understand what their current mechanical systems are capable of and how they can adjust the function of those systems to optimize their capabilities.

Before School Opens:

1. Commission building mechanical systems for full occupancy (see details below for tips about how and why to commission mechanical systems for fall start-up).
2. Operate all ventilation systems at full capacity for one (1) week prior to the reopening of school buildings.
3. Discuss with the entire facilities team and school administrators the general principles about what changes are planned to the usual ventilation system operation for the coming year. It will be important to communicate with school staff the importance of not making any adjustments to the mechanical systems inside school buildings (thermostats, fan speeds, etc.) without input from the facilities team.

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After School Opens:

1. Flush the air inside the building for a minimum of two (2) hours prior to occupancy and one (1) hour after occupancy (after the night-shift custodians leave), with the dampers open as fully as possible (i.e. to maximize fresh air intake) during this flushing period.

2. Program and lock fan schedules to align with the building occupancy schedule (i.e. provide flushing ventilation starting two (2) hours before building occupancy and one (1) hour post occupancy).

3. Develop a system for building users to notify the facilities department if the building needs to be open longer than usual so that the fan schedule can be altered for that day.

4. Keep the ventilation system running during all hours that the building is occupied.

5. Do not allow teachers or other staff to make changes to ventilation system controls in their respective rooms. Explain to them the importance of keeping fans running all day. If temperature, noise, or other issues exist in certain areas, encourage staff to discuss the problem with the facilities department to try to identify a suitable fix that does not negatively impact ventilation.

6. Keep bathroom exhaust systems running all day, every day (24 hours a day/7 days a week).

7. For isolation rooms to be used for holding sick students prior to dismissal, consider adding supplemental filtration, such as a portable air cleaner. This is particularly important if the ventilation serving those rooms cannot be run at 100% exhaust at all times. If a portable air cleaner is used, it should:

    - Contain HEPA filters only without ionizers, ozone generators, UV light, or other add-ons.
    - Be correctly sized for the space, with an appropriate CADR (clean air delivery rate).
    - Be located for greatest efficiency within the space.
    - Be turned on at all times that the space is occupied.

8. Develop a specific plan for performing routine inspections and maintenance of mechanical systems, as specified in the commissioning process.

9. For buildings without central ventilation systems or with certain areas not served by the central ventilation system, there are other important design considerations facility managers should be aware of, and in control of, in order to maximize available dilution ventilation and minimize the spread of virus particles inside their facilities.

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- At a minimum, where temperature allows and no other means of ventilation is available, windows should be opened to allow for some minimum level of fresh air exchange into occupied spaces.
- Window air conditioning units should be adjusted to maximize fresh air intake into the system. Air conditioner blower fans should be set on low speed and pointed away from room occupants to the extent possible.
- Ceiling fans should be adjusted so that fins are rotating in a direction that draws air up toward the ceiling rather than down onto occupants.
- Window fans should be turned to exhaust air out of the window in the direction of the outdoors. Ensure that fans are not blowing out of windows directly into walking paths or areas where individuals may congregate.
- Window fans that blow air into a room or free-standing fans that only serve to circulate existing air around a room should not be used.
- In addition, we do not recommend separate, free-standing air cleaner or HEPA filter units for individual classrooms. These units are highly variable in their effectiveness in larger open spaces such as classrooms and in general, any effect on indoor air quality is likely insignificant and greatly outweighed by the additional costs to school systems.

How to Commission Building Mechanical Systems for fall school reopening

1. If your school system does not already have one that it routinely works with, hire a mechanical engineering firm with a proven track record in evaluating, adjusting, and balancing ventilation systems, particularly ventilation systems in school buildings, to commission all of the buildings' mechanical systems for full occupancy. The school facilities manager should be part of the discussion team talking with the engineering firm and the commissioning agent.

   Consider asking your Commissioning Agent the following questions:

   - How many and what types of systems serve your buildings, and which area of the building does each separate system serve?
   - What are the capabilities of the systems present in your school buildings?
   - Are the systems currently working to their full capabilities?
   - Are the current systems' capabilities enough to satisfy full capacity for how the buildings need to operate now?
   - Can demand-based systems be converted to constant volume until cooling season is over (if systems provide central cooling)? During heating season? Longer-term?

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- Can recirculation of air be suspended (economizers disabled)?
- Can they provide a summary of performance expectations for mechanical systems in the building?

2. Include the following items in the commissioning process:

- A complete set of measurements to understand total air distribution throughout the building.
- Inspection and evaluation of all building ventilation systems, both automated and manual.
- Air balancing and appropriate retesting to ensure parameters that satisfy the conditions of full occupancy of the buildings.
- Inspections:
  - Filter frames - Decide what kind of filter thickness and type you will be using if you decide to upgrade to a higher-rated filter. Discuss this with your ventilation engineering firm. Either way, all filter frames will need to be inspected. Replace or fix all bent, broken, misshapen frames to prevent air from by-passing the filter.
  - Dampers and all associated controllers and actuators need to be visually inspected. Do not rely only on looking at a computer screen if you have an automated building system.
  - Inspect, verify, and modify automated set points, if needed. Discuss both temperature and CO_2 set points in newer buildings that utilize these variables for automated decision-making.
  - Locations of supply and return diffusers. Look at ventilation effectiveness and whether short-circuiting is occurring. This happens frequently when supply and return diffusers are too close to each other. Discuss the possibility of moving them farther apart if this is occurring. If supplies and returns are ducted using flex duct and the room has a suspended ceiling, relocating can be performed more easily.

  - Air balancing, inspections, and other work should be performed in accordance with one of these certification bodies: NEBB (https://www.nebb.org/); TABB (https://www.tabbcertified.org/); AABC (https://www.aabc.com/)

3. Strive toward the following ventilation goals.

- Increase outdoor air ventilation as much as possible by disabling demand-controlled ventilation systems and opening outdoor air dampers to 100%, as indoor and outdoor conditions permit. Disabling demand-based systems will allow fans to run continuously.
- Tune ventilation systems to enable them to perform to the maximum capacity consistent with full occupancy conditions for the building.

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- Bypass energy recovery ventilation systems that leak or recirculate potentially contaminated exhaust air back into the outdoor air supply.
- Once fans are running continuously, provide increased particle capture by increasing air filtering capacity through repair/upgrades to current system, where needed. This includes filter frames, filter configuration, and filter rating (ASHRAE recommends striving for filters with a MERV-13 rating where possible).

Why it is Important to Commission Building Mechanical Systems

1. Commissioning verifies that existing equipment is working properly. Adjustments can then be made to allow current systems to operate to the best of their ability.
2. Adjusting mechanical systems to satisfy full building occupancy, even if buildings will have reduced occupancy in the fall, will result in increased ventilation per person without over-taxing the equipment and potentially causing premature equipment failure.
3. Commissioning reduces the likelihood of unintended consequences of making changes to how systems operate.
4. If one or more of the systems are deemed to be inadequate, commissioning will provide the basis for making informed and intelligent decisions about next steps to improve those systems.
5. The cost for commissioning is money well spent because it will prevent building operators from spending money on things that add little value and instead, help them focus attention on things that will make a real difference.

Additional resources:

- AICARR- Decision Tree: Protocol for risk reduction of SARS-CoV2-19 Diffusion With the Aid of Existing Air Conditioning and Ventilation Systems
- Air filtration and COVID-19: Indoor air quality expert explains how to keep you and your building safe: Interview with Professor Jeffrey Seigel, University of Toronto
- The Path to COVID-19 Recovery: How To Improve Indoor Air Quality When Re- Opening K-12 Schools. Univ Calif Davis.

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