Worcester Public Schools

Ventilation Assessment
&
COVID-19
Mitigation Strategies

for

May Street School
Worcester, MA

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Worcester Public Schools

A. Preface:

Worcester Public School has as Nault Architects Inc. and their consultant Seaman Engineering Corporation (SEC) to review all of their occupied buildings and comment on existing natural and mechanical ventilation.

The first part of the report is SEC's evaluation of the existing mechanical systems.

The second part of the report is an evaluation of the natural ventilation. The Building Code requires ventilation of each occupied space and that can be achieved either through mechanical of natural ventilation methods. If the natural ventilation path is chosen, there must be a clear opening(s) in the space that meet or exceed the 4% of the total room square footage. After the field survey of each room / window type was complete, the ventilation information was added to a spread sheet for calculation of the 4% and color-coding. The calculations were also color-coded on a floor plans of the building for a better overall understanding of the existing conditions.

The natural ventilation color-coding (on the spreadsheet and plans) is as follows:

- **Green Spaces**: meets or exceed the code minimum natural ventilation.
- **Yellow Spaces**: does **not** meet the code minimum natural ventilation, but does have operable window to allow some natural ventilation.
- **Red Spaces**: does not meet the code minimum natural ventilation and does not have any operable windows.

It should be reiterated that the second part of this report is only measuring natural ventilation. Therefore, newer buildings or buildings with large amounts of fixed windows may have large amounts of red and/or yellow spaces, but that doesn't mean they are not code compliant, they may be relying on mechanical ventilation. However, for this part of the report, were asked to show a baseline for all schools without mechanical equipment.

B. Building Description:

May Street School:
May Street School is located in the Doherty Quadrant of Worcester at 265 May Street. The school was built in 1927, houses grades PK-06, has 15 classrooms and the building is 35,912 square feet. The windows in this building were replaced in 2012.

C. Table of Contents:

1) Mechanical Ventilation Report

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I. EXECUTIVE SUMMARY

This report briefly describes the existing ventilation systems at the May Street School in Worcester, MA as well as their capabilities to support current code required ventilation rates. In addition, we have evaluated the systems ability to support recommendations in accordance with the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Epidemic Task Force Building Readiness Guidelines (updated 10-20-2020). Several of the ASHRAE recommendations as well as those from the Harvard T.H. Chan School of Public Health and other industry sources have been presented for consideration to assist in further mitigating virus transmission through the buildings heating, ventilation, and air conditioning (HVAC) systems.

Our inspection of the existing systems was limited to visual observations coupled with review of original design drawings, when available. The findings presented in this report presume the systems are operational and delivering air quantities indicated on the original design drawings. Proper operational testing of each piece of equipment and airflow measuring would be required to confirm such operation.

During, our visual inspection we also took several spot measurements of air quality in various locations throughout the school. Measurements taken were limited to Temperature (°F), Relative Humidity (% RH), CO_2 (carbon dioxide in ppm), CH_2O (formaldehyde in ppm) and Total Volatile Organic Compounds (TVOC in ppm).

The results of the readings taken during our inspection were only used to identify areas where possible ventilation issues may exist and/or to identify areas where a source contaminant may be causing elevated levels.

COVID-19 Control Measures:

In line with the current American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Epidemic Task Force Building Readiness Guidelines (updated 10-20-2020) and those from the Harvard T.H. Chan School of Public Health - 5-Step Guide to Checking Ventilation Rates in Classrooms, as well as other industry recommendations the following HVAC COVID Control Measures (CCM's) are presented for consideration to assist in mitigating virus transmission thru the HVAC systems. The following descriptions are abbreviated with additional detail found later within the report.

As of the writing of this report, the City of Worcester Public Schools (WPS) has already begun implementation of several of the measures noted below where possible. For enhanced measures WPS has begun to incorporate Bipolar Ionization (see ECCM-#3) extensively throughout the May Street School to address the current pandemic condition.

CCM #1 – Pre & Post Purge Ventilation – Pre- and post-purge ventilation of occupiable spaces using outside air introduced thru the HVAC systems for an extended period of time prior to and after occupancy.

The building has a mix of HVAC system types many of which appear to be capable of implementing this measure presuming the systems are in operational order.

CCM #2 – Increased Ventilation - Increase the quantity of outdoor air ventilation for improved space dilution where systems allow. Disable demand ventilation reset. The Harvard T.H. Chan School of Public Health identifies 3 outdoor air changes per hour (ACH) as the "bare minimum" during a pandemic condition.

The building has a mix of HVAC system types many of which appear to be capable of implementing this measure presuming the systems are in operational order.

CCM #3 – Improved Filtration - Improve filtration to up to MERV-13 or higher on recirculating air handling systems which can support such filtration.

The unit ventilators in the school will not support increased filtration above MERV 8 either due to physical equipment limitations (i.e., unit ventilators limited to 1" filters) or due to fan capacity limitations. The air handling systems serving the gym and one serving the locker room may not be capable of supporting increased filter efficiency. A newer air handler serving a nurse's areas is also small and may not be able to support filtration above MERV 8. Increased filtration efficiency can lead to faster filter loading and a potential reduction in ventilation air for systems not designed to support this filtration level.

In addition to the above suggested measures, we have also presented Enhanced HVAC COVID-19 Control Measures (ECCM) which could be considered for implementation. Where the above CCM's cannot be employed, one or more of the ECCM measures outlined herein may be utilized to improve indoor air quality. The following descriptions are abbreviated with additional detail found later within the report:

ECCM #1: Portable Room Purifiers - Portable room air purifiers may be used in select areas to help clean the air within that space. These can be especially helpful where rooms have low outdoor air changes per hour and cannot be supplied with additional outdoor air or where existing systems cannot accommodate improved filtration.

ECCM #2: UV-C Light Sterilization - UV-C lights may be considered for insertion in equipment and ductwork to help neutralize viruses as it is exposed to the light.

ECCM #3: Bipolar Ionization - Air ionizers may be installed in air handling systems or portable units installed in rooms to improve indoor air quality. These systems cause particles and airborne contaminants to bind together thereby increasing their size, so they tend to either drop out of the breathing zone or be better removed by air filtration. Recent studies have also shown Bipolar Ionization may inhibit the COVID-19 virus's ability to infect.

WPS has begun to incorporate Bipolar Ionization extensively throughout the May Street School to address the current pandemic condition.

Recommendations Summary:

Based on our site inspections, sample air quality readings and review of original drawings we found that a majority of the occupied areas of the May Street School appear to have systems with the potential to comply with current ventilation codes, pending balancing and verification, with few exceptions noted herein. However, in order to address the pandemic level conditions currently in place the following table summarizes our recommendations, several of which, align with the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Epidemic Task Force Building Readiness Guidelines (updated 10-20-2020) as well as those from the Harvard T.H. Chan School of Public Health.

WPS has already begun to incorporate Bipolar Ionization (ECCM-#3) extensively throughout the May Street School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
Gymnasium	AHU-1 & 2	CCM-#1 & #2 ECCM - #3
General Classrooms	Unit Ventilators & Vent Shafts	CCM - #1 & #2 ECCM - #3
Nurses Office & Locker Room	AHU-# & # (not defined)	CCM - #1 & #2 (locker room already 100% OA) ECCM - #1 or #3 (*see note below) Ensure AHU-#'s are on EMS and bring in OA

*<u>Note</u>: *For individual classrooms and other areas noted, ECCM #1 – Portable Air Filtration and/or ECCM #3 – Ionization, are noted as possible options to improve air cleaning and changeover during pandemic conditions.*

Inevitably, during a pandemic, the best approach is a multi-faceted one which should include the above HVAC strategies as well as proper housekeeping (cleaning of spaces and surfaces), occupant actions (hand cleaning, wearing masks, social distancing, following recommended CDC guidelines) and other mitigation strategies.

II. HVAC VENTILATION ASSESSMENT

A. GENERAL

Over the last several weeks we performed site inspections of the existing school building to assess the ventilation systems in place. Manufacturer and model information was obtained from the existing ventilation equipment, when available/accessible, and visual conditions were noted.

For our review, original design drawings as well as drawings of various modifications over the years for the school were received from school facilities. In addition, we have also received and reviewed the available HVAC control drawings to ascertain current control configuration. We have used these documents to ascertain the original design ventilation rates so as to compare them to current ventilation codes and standards.

Our inspection was limited to visual assessment of systems and did not include operational testing of each piece of equipment or airflow measuring. We have however, taken some spot measurements of air quality in various locations throughout the school. Measurements taken were limited to:

- Temperature (°F)
- Relative Humidity (% RH)
- CO_2 (carbon dioxide in ppm)
- CH_2O (formaldehyde in ppm)
- Total Volatile Organic Compounds (TVOC in ppm)

These readings were taken at a specific moment in time and may vary during the day based on space occupancy, use and activities as well as the operational state of the HVAC systems. For example, most all spaces surveyed were unoccupied or very lightly occupied and as such most all CO_2 levels were low since space CO_2 is primarily generated by occupants.

TVOC's sources can vary widely and include but are not limited to paints, finishes, adhesives, cigarette smoke, pesticides, personal care products, car exhaust, new furnishings, wall coverings, cleansers, and cooking fuels. The meter used included the following chemicals in its TVOC analysis: Acetone, Ethylene Glycol, Formaldehyde, Xylene, 1,3-Butadiene, Tetrachloroethene, Hydrogen Sulfide, Ammonia, Toluene, Benzene, Methylene Chloride, Perchloroethylene, and MTBE. The meter cannot read every possible VOC nor quantify percentages of various VOC's. In addition, we did notice the TVOC readings tended to drift up during the study, possibly due to a calibration issue, as such, the readings in this report were only used to identify areas where possible ventilation issues may exist and/or to identify areas where a source contaminant may be causing elevated levels.

The report ventilation calculations presume, the existing systems are operating to the levels reflected on the original design drawings. Testing and Balancing by a certified balancer would be required to confirm actual airflows.

For ventilation calculations, data from current codes including the International Mechanical Code (IMC) 2015 and ASHRAE 62.1-Ventilation for Acceptable Indoor Air Quality were used. The outdoor airflow values have been corrected to adjust for the distribution systems ability to get the outdoor air to the space breathing zone with the breathing zone being within 6 feet of the occupied floor. This correction factor also known as the Zone Air Distribution Effectiveness (ZDE), varies based on how and where the air is introduced and removed from the room as well as the temperature of the air entering the room. Some examples of ZDE for various systems are as follows:

Distribution Configuration	ZDE
Ceiling supply of cool air (air below room temp.)	1.0
Ceiling supply of warm air & floor return	1.0
Clg. supply of warm Air >15F above space temp. & clg. return	0.8
Floor supply of warm air & floor return	1.0
Floor supply of warm air & ceiling return	0.7
Displacement cooling floor supply & ceiling return	1.2

For example, a displacement cooling system with a ZDE of 1.2 would require 17% (1.0 / 1.2) less outside air to properly ventilate a space than a system with warm air supplied at the ceiling level being that the displacement system is more effective in getting the outdoor air into the breathing zone. A room with a ZDE of 0.8 would require 25% (1.0 / 0.8) more outdoor air to comply with ventilation standards.

This report contains a brief description of the types of ventilation systems serving the building as well as makes recommendations, where applicable, to improve ventilation of area served by these systems. Our evaluation considered the recommendations made by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Epidemic Task Force Building Readiness Guidelines (updated 10-20-2020) as well as those from the Harvard T.H. Chan School of Public Health and other industry sources. All to assist in further mitigating virus transmission through the buildings heating, ventilation, and air conditioning (HVAC) systems.

B. EVALUATION

The following evaluation is based on visual observation of systems and equipment and excludes any operational testing which we understand is on-going by WPS. Evaluation includes information obtained from Worcester Public Schools on current air filters as well as existing building mechanical plans when available. In some cases, equipment was not accessible, and assessment was based only on original design drawings where available.

General Classrooms & Misc. Areas:

A majority of the classrooms in the building are heated with a mix of classroom unit ventilators and radiators. Ventilation for some rooms appear to be tied to a gravity driven ventilation system. The operational condition of this system is unknown and is not clearly identified on control drawings. The rooms with UV's are fitted with air 1" thick filters with an estimated MERV rating of 7 or 8 which is typical for units of this type. These units can support a maximum filter efficiency of MERV 8.

The rooms with classroom unit ventilators are connected to louvers along exterior walls with each having an associated control damper to allow outdoor air to enter the classroom space through the unit ventilator. Existing control drawings reflect control of these UV systems to some extent with reference to existing pneumatic controls as well. The control drawings reflect a sequence of operation that cycles the fans of the UV's based on space temp. regardless of occupancy mode which would not provide continuous ventilation during occupied periods. Typically, during occupied periods, the unit fans would be configured to run continuous to provide space ventilation and electric operators modulate the steam valve, face & bypass dampers (where applicable) and mixing dampers to maintain space temperature setpoint. During unoccupied periods, the fans cycle off and only cycle on with the associated steam valve opening when there is a need for heating or economizer (OA) cooling. Control operation should be verified to insure continuous ventilation during occupied periods. Old drawings show 630 CFM of outdoor air being introduced to classrooms through the unit ventilator system.

The operation of the ducted shaft ventilation system serving several classrooms is unknown and is not reflected on existing control drawings. Further review of this system would be required to ascertain its operational condition and capabilities.

For a standard classroom, current code would require 10 CFM per person of outside air plus 0.12 CFM per SF. For a system with a presumed zone air distribution effectiveness of 1.0, a room size of 800 SF with 26 occupants (25 students + 1 teacher) would require 356 CFM of outdoor air (445 CFM if ZDE = 0.8). As such, for the UV systems, more than the required code outside air is being supplied. Testing and Balancing of these and other systems, would be required to confirm outdoor airflow rates.

Bathroom and local exhaust requirements are supported by sidewall and roof mounted centrifugal exhaust fans of unknown capacity.

Gymnasium:

The gymnasium space is supported by a two (2) mixed style air handling units. The volume of outdoor air the system moves is unknown however, old drawings show their full 100% outdoor air capacity. The drawings reflect occupancy sensor-based control which apparently enables and disables the system into occupied mode based on room occupancy. The drawings do not clarify the sequence of operation of the unit beyond the occupancy sensor interface and do show an existing pneumatic control for the outside air and recirculation dampers.

Due to the age of these units, we would not recommend filtration in excess of MERV 8 as their fans are presumed to not have the ability to support such. Increase filtration efficiency can lead to faster filter loading and a potential reduction in ventilation air for systems not designed to support this filtration level.

Science & Art Rooms:

There are no assigned science or art rooms indicated on the plans. Per the current code, science rooms and art rooms require higher ventilation levels than general use classrooms with a driving factor being required exhaust air. For science laboratories 1 CFM per SF of exhaust is required and for art rooms 0.7 CFM of exhaust is required along with the associated make-up air.

Nurse:

There is a newer air handler installed in the nurse's area. We were unable to access this unit during our inspection, so we were not able to obtain filter information or if the unit introduces any outside air. A portion of the office area appears to be supported by the old shaft ventilation system whose operational condition is unknown. Other office spaces appear to have no ventilation other than what could be afforded via operable windows.

Controls:

Controls in the building appear to be fairly distributed but not comprehensive. As a minimum, from the control drawings it appears the building energy management system (EMS) controls the unit ventilators and the gym AHU units. There are existing pneumatic controls on these systems as well. The EMS system is currently supported by Automated Building Systems, Inc (ABS). Upgrade of controls may be required to implement the CCM's noted herein. Further review with the EMS vendor would be required to ascertain the extent of this system.

The operating schedule for much of the equipment is based on the school's occupancy schedule. The schedule is adjustable via the front-end computer workstation.

C. IAQ & Ventilation Summary

IAQ Summary:

During our inspection we obtained spot measurements of air quality in various locations throughout the school. Measurements taken were limited to:

- Temperature (°F)
- Relative Humidity (% RH)
- CO_2 (carbon dioxide in ppm)
- CH_2O (formaldehyde in ppm)
- Total Volatile Organic Compounds (TVOC in ppm)

The readings were taken at a specific moment in time and may vary during the day based on space occupancy, use and activities as well as the operational state of the HVAC systems. For example, most all spaces surveyed were unoccupied or very lightly occupied and as such most all CO_2 levels were low since space CO_2 is primarily generated by occupants.

In addition, we noted some elevated TVOC levels and/or formaldehyde levels in areas which would not generally be expected to have such elevated levels. Although TVOC's (which includes formaldehyde) may come from varied sources such as cleaners, air fresheners and such, formaldehyde levels are often from off-gassing of furnishings or building materials. It is important to note that elevated levels of TVOC's may have been partially caused by recent enhanced cleaning measures or due to ventilation systems that were not in full operation at the time.

Measurements taken included space humidity. Humidity levels has been found to play a role in the controlling the spread of COVID-19. ASHRAE recommends winter humidity levels be kept between 40% to 50% and summer humidity levels between 50% and 60% with a summer target of 50%. Maintaining humidity levels within the above ranges has been found to limit the growth and transmission of certain bacteria and viruses as well as supports respiratory function. The below chart is taken from the 2020 ASHRAE Handbook – HVAC Systems and Equipment and reflects the impact of space humidity on the increase or decrease of effect on various space contaminants. This chart only reflects increase or decrease of effect from humidity and does not intend to imply that there is zero growth or impact of a certain contaminant when the sloped bar graph zero's out.

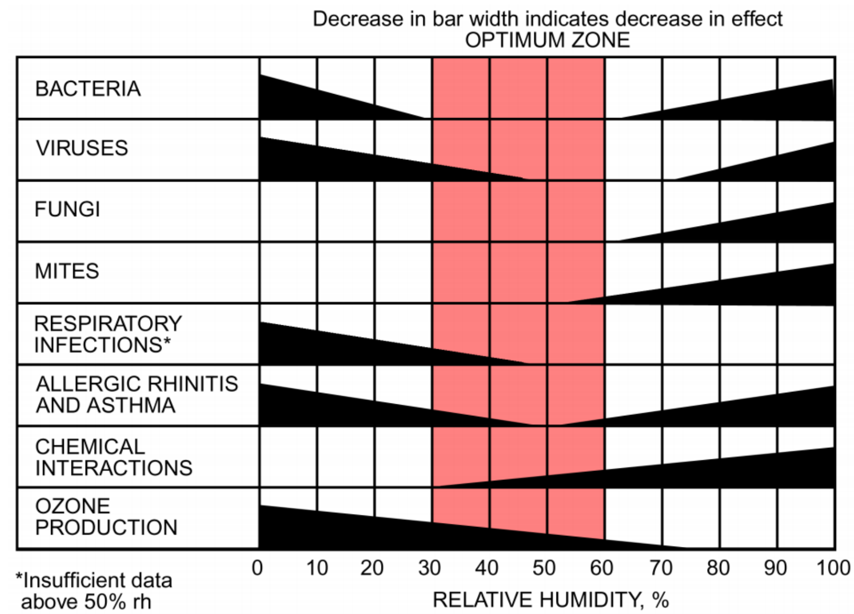

Fig. 1 Optimum Humidity Range for Human Comfort and Health
(Adapted from Sterling et al. 1985)

The May Street School HVAC systems have no active humidity control. Space dehumidification is limited only to those areas which have air conditioning cooling. However, this dehumidification is not actively controlled by a humidity setpoint. Moisture removal only occurs when these systems are operating in the cooling mode. As such, space humidity may climb above 60% during periods when low thermal loads require less cooling (i.e., a cool damp day) or swing above and below 60% as the systems cycle based on space temperature.

Caution must be taken when considering adding active humidification to existing buildings as it is imperative that the buildings thermal envelope and vapor barriers be reviewed. Older structures, such as May Street School often have poor vapor barrier the varying wall and window construction and thermal characteristics may limit the ability for active humidification. Adding humidity in the wintertime without consideration of the building construction could result in moisture condensation on windows and within wall assemblies which may create a damaging and unhealthy condition for the building and its occupants. Review of the building envelope should take place prior to consideration of the addition of any humidification system. As such, our recommendations contained with this report exclude active humidification control until such time as the envelope can be reviewed.

The IAQ readings taken during the time of the inspection are contained within the table below. In addition, the table reflects the outdoor air exchange rate in the rooms based on design data from existing plans.

The document entitled “5-Step Guide to Checking Ventilation Rates in Classrooms” from the Harvard T.H. Chan School of Public Health recommends a target outdoor air exchange rate during these pandemic conditions. The document identifies 5 air changes per hour (ACH) and above as "excellent" down to a 3 ACH being considered "bare minimum". Many of the general classrooms in the May Street School supported by unit ventilators appear to have a design outdoor air exchange rate of 3 ones without UV's are presumed to be lower. When the outdoor air exchange rate is lower than the target 5 ACH, the document recommends the following strategies:

1. Increase outdoor air (see CCM #2)
2. Use MERV 13 filters (or greater) on recirculated air (see CCM #3)
3. Add portable air cleaners with HEPA filters to the classroom (see ECCM #1)

It should be made clear however, that a room that has less that what this document considers the bare minimum outdoor air exchange rate may meet or exceed the most current ventilation standards dependent on the pace occupancy and therefore may not be considered under ventilated by code standards. The 5 ACH or greater recommendation is meant to address the pandemic conditions being experienced as this level of ACH would equate to nearly 100% outside air requirement for a conventional mixed air cooling & heating system.

The following tables describe areas and systems where the above measures as well as others presented in this report may be applied.

May St School IAQ Sampling Summary

Space Tested	Temp. °F	Humidity % RH	CO2 %	TVOC ppm	HCHO ppm	Room Area SqFt	Room Height Ft	Volume Cubic Ft	Original Design OA CFM	OA ACH	Notes
Basement											
Library	74.8	24.2	463	1.4	0.17	1560	10	15600	2520	9.7	a
Conference Rm "Office"	74.6	24.2	507	1.4	0.18	171	9.41	1609	N/A	N/A	
Large Cafeteria	75.2	19	426	1.41	0.18	1711	10.66	18239	N/A	N/A	
Kitchen	77.4	18.3	428	1.44	0.21	699	10.08	7046	N/A	N/A	
Art Room	76.2	25.2	469	1.48	0.2	335	10.08	3377	N/A	N/A	
Gym	71	17.9	427	1.38	0.19	6223	19.91	123900	10000	4.8	a
1 on 1 Rm (old assistant principal)	75.1	24.4	450	1.42	0.19	114	10	1140	N/A	N/A	
First Floor											
Classroom 7	72.7	27.8	446	1.42	0.18	1046	12.25	12814	650	3	
Main Office	68.4	31.1	552	1.71	0.24	2285	12	27420	N/A	N/A	
Classroom 4	71.2	26.9	449	1.44	0.18	785	12	9420	650	4.1	
Room B "resource room"	69.8	29.9	440	1.43	0.14	180	8.83	1589	N/A	N/A	
Second Floor											
Nurse	73.6	24.9	483	1.51	0.19	254	12	3048	N/A	N/A	
Classroom 9	72.2	25.7	466	1.51	0.21	802	12	9624	N/A	N/A	
Principal	70.7	26.7	467	1.42	0.18	257	12	3084	N/A	N/A	
Gym 10	75.6	40.4	443	1.38	0.18	729	11.25	8201	N/A	N/A	
F.S.A's Office	75	42.1	469	1.39	0.17	180	11	1980	N/A	N/A	

Note: As noted previously, the TVOC readings tended to drift up during the study, possibly due to a calibration issue, as such, the readings in this report were only used to identify areas where possible ventilation issues may exist and/or to identify areas where a source contaminant may be causing elevated levels.

a. The airflow indicated is based on 100% OA which would not be a normal mode of operation.

Ventilation System Summary & Recommendations:

The following table is based on original design drawings and reflect most of the systems which provide ventilation air to the building. The units ID tag, area served, ventilation data and filter efficiencies are listed. The table also reflects possible COVID Control Measures (CCM) and Enhanced COVID Control Measures (ECCM) described later in this report which may apply to such systems to improve performance either during pandemic conditions and/or post pandemic conditions.

We highly recommend at least minimum outdoor air be provided in areas which do not have such systems or if existing ventilation systems are not operational. For example, office areas should be supplied with OA ventilation as none appears to exist.

May Street Ventilation System Summary

Unit ID	Area Served	Exist. Supply CFM	Exist. O.A. CFM	Exist. O.A. %	Exist. Filter Qty & Size	Exist. Filter MERV Rating	Exist. Filter Vel. (FPM)	Proposed CCM #	Proposed ECCM #	Notes
AHU-1 & 2	Gym	5,000 each	N/A	N/A	(2)24x24x2 (2)12x24x2	8	417	#1, #2	#1, #3	a
AHU-#	Nurse	N/A	N/A	N/A	(1) 20x20x1	8	N/A	#1, #2	#1, #3	a
UV	Library	1,250	1,250	100	unknown	N/A	N/A	#1, #2	#1, #3	a
Misc. UV's	Classrooms	1250	630	50%	(1) 14x43.75x1	8	294	#1, #2	#1, #3	a
Vent Shaft	Classrooms	N/A	N/A	N/A	N/A	8	N/A		#1, #3	b

Ventilation System Summary Notes:

a. *For individual classrooms and other areas noted, ECCM #1 – Portable Air Filtration and/or ECCM #3 – Ionization, are noted as possible options to improve air cleaning and changeover during pandemic conditions. During pandemic conditions, disable gym AHU occupancy sensors so as to maintain continuous ventilation during occupied periods.*

b. *We highly recommend outdoor air of some level be provided for areas having none, even if via windows, as there is no substitute for proper ventilation regardless of other measures employed.*

II. COVID-19 HVAC MITIGATION MEASURES

A. HVAC COVID-19 CONTROL MEASURES

In line with the current American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Epidemic Task Force Building Readiness Guidelines (updated 10-20-2020) and those from the Harvard T.H. Chan School of Public Health - 5-Step Guide to Checking Ventilation Rates in Classrooms, as well as other industry recommendations the following HVAC COVID Control Measures (CCM's) are presented for consideration to assist in mitigating virus transmission thru the HVAC systems.

The ASHRAE Epidemic Task Force recommends several measures to assist in COVID-19 mitigation with more aggressive action with epidemic conditions in place (ECiP) and post-epidemic conditions in place (P-ECiP). For ECiP conditions in place the HVAC COVID-19 Control Measures (CCM) that could be readily applied to the May Street School surveyed are outline herein. Refer to the Ventilation System Summary Table for applicable CCM recommendations.

It is imperative that all systems be maintained and checked to confirm proper operation in line with their original design, adjusted where applicable, as described herein. In addition, a Testing and Balancing company should be enlisted to adjust and confirm all systems are properly achieving their design outdoor air, supply air and exhaust air levels.

<u>CCM #1</u> – Pre & Post Purge

Pre- and post-purge ventilation of occupiable spaces using outside air introduced the HVAC systems. This would be accomplished by starting the ventilation systems in occupied mode (i.e., OA at design or higher) 4 hours prior to schedule building occupancy and maintain the occupied mode for 4-hours after occupancy ends.

The building has a mix of HVAC system types many of which appear to be capable of implementing this measure presuming the systems are in operational order.

<u>CCM #2 – Increased Ventilation</u>

Increase outdoor air ventilation for improved space dilution where systems allow. This would entail increasing the minimum outdoor air damper positions on all mixed air style systems within the limits of the equipment capacity and overriding any demand ventilation reset schemes (i.e., CO_2 reset). A control sequence would need to be implemented for the respective air handlers which would limit the outdoor air volume to the unit's respective capability such that proper control of the discharge air can be maintained as well as freeze protection of coils. In addition, sequence would need to include limitation based on boiler plant and cooling system capabilities and summertime moisture limitations. For buildings which have anti-freeze in water-based heating and/or cooling systems concern of unitary coil freeze up is reduced.

The building has a mix of HVAC system types many of which appear to be capable of implementing this measure presuming the systems are in operational order.

<u>CCM #3 – Improved Filtration</u> - Improve filtration to up to MERV-13 or higher on recirculating air handling systems which can support such filtration.

The unit ventilators in the school will not support increased filtration above MERV 8 either due to physical equipment limitations (i.e., unit ventilators limited to 1" filters) or due to fan capacity limitations. The air handling systems serving the gym and one serving the locker rooms are old and may not be capable of supporting increased filter efficiency. A newer air handler serving a nurse's areas is also small and may not be able to support filtration above MERV 8. Increased filtration efficiency can lead to faster filter loading and a potential reduction in ventilation air for systems not designed to support this filtration level.

Prior to implementation of higher filtration levels in excess of MERV 8, existing AHU equipment capabilities must be reviewed to verify it can support the added pressure drop imposed by MERV-13 filtration. Testing and Balancing to confirm current airflow, pressure drops, and fan motor power coupled with manuf. published data would be required to confirm the unit's capability for improved filtration.

B. ENHANCED HVAC COVID-19 CONTROL MEASURES

In addition to the suggested above measures below are some Enhanced HVAC COVID-19 Control Measures (ECCM) which could be considered for implementation. Refer to the Ventilation System Summary Table under the respective schools for applicable recommendations.

ECCM #1: Portable Room Purifiers

Portable room air purifiers could be used in select areas to help clean the air within that space. These could be applied in areas such as those where the population is in a higher risk group of developing COVID-19 complications or anywhere where real time space cleaning is required such as the nurse's office. Products which include HEPA filters and fans with air exchange rate appropriate for the size room should be selected.

ECCM #2: UV-C Light Sterilization

UV-C lights can be inserted in equipment and ductwork to help neutralize viruses as it is exposed to the light. UV technology has been studied and used extensively, primarily in hospital settings for virus and bacteria control and in the general HVAC primarily to prevent build-up on coils. To properly mitigate the virus an extended run of return air duct would need to be identified to allow for adequate exposure to UV-C light since a light bar just at the unit coil or filter will primarily just prevent build-up of mold, bacteria, and viruses on those surfaces.

ECCM #3: Bi-Polar Ionization

Air ionizers are meant to be installed in the supply air duct or plenum downstream of fans and filters. They are also offered as portable units for room application. In May Street School's case they could be installed in the supply air duct of the respective mixed air handling systems, in unit ventilators and portable units may be considered. WPS has already begun to incorporate Bipolar Ionization extensively throughout the May Street School to address the current pandemic condition.

Air ionizers appear to be showing quite a bit of promise for low system impact in retrofit applications. For years, these products have been used to primarily clean air of dust and particles by forcing the particles to bind together and either drop out of the breathing zone and/or better be able to be captured by HVAC system air filters by making particles larger. Recently, there are studies which claim to show that ionizers work on neutralizing virus's in the space prior to needing to draw these pollutants back to the units where filters and/or other cleaning technology such as UV-C could occur.

ASHRAE has not taken a definitive stance on Bipolar Ionization with regard to virus mitigation as of yet and has deferred to CDC's comment that it is still considered an emerging technology in this regard. Bipolar Ionization has been used for decades primarily for the removal of particles within the air. During that period, its use was focused more on facilities such as convention centers, airports, casinos, and the like as there are large amounts of occupant and activity generated pollutants. Only recently has Bipolar Ionization been looked at for virus mitigation which is why ASHRAE and CDC still view it as an emerging technology being that there are not extensive 3rd party studies and reviews of its capability in this regard.

That said, even ignoring its potential virus neutralizing capabilities, the ability of the product to bind smaller particles into larger particles results in an overall desirable indoor air quality benefit in that it increases the capabilities of air filters to filter the air as well as promotes particles to drop out of the breathing zone. We do, however, recommend the technology be provided on systems that meet code required outdoor air ventilation levels as this technology is not a replacement for outdoor air.

Inevitably, during an epidemic, the best approach is a multi-faceted one and should include the above HVAC strategies as well as proper housekeeping (cleaning of spaces and surfaces), occupant actions (hand cleaning, wearing masks, social distancing, following recommended CDC guidelines) and other mitigation strategies.

2) Natural Ventilation Summary

May Street School - Basement

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	A 3.66 AWNING	B 7.02 AWNING	C 8.19 HOPPER	D 3.58 HOPPER	E 5.95 HOPPER	F 3.11 HOPPER	G 4.67 HOPPER	H 7.38 HOPPER	J 8.26 HOPPER	K 4.55 AWNING	L 5.55 AWNING	Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
Basement																		
Conference Room	conference	171	6.84					2							11.91	-5.07	YES	
Library	media	1560	62.4		3	3	2								52.80	9.60	NO	
Assistant Principal	office	114	4.56	1											3.66	0.90	NO	
H/C Bathroom + Entry	toilet	138	5.52						2						6.22	-0.70	YES	
Resourse Room	classroom	342	13.68							2	1				16.72	-3.04	YES	
Toilet	toilet	29	1.16												0.00	1.16	NO	
Kitchen	kitchen	699	27.96		2										14.05	13.91	NO	
Supply Closet	storage	63	2.52												0.00	2.52	NO	
Custodian's Office	office	115	4.6												0.00	4.60	NO	
Large Cafeteria	café	1711	68.44		2							1			22.31	46.13	NO	
Art Room	classroom	336	13.44		1										7.02	6.42	NO	
Computer Room + Vestibule	classroom	560	22.4		2										14.05	8.35	NO	
Girl's Room + Vestibule	toilet	130	5.2	1											3.66	1.54	NO	
Boy's Room	toilet	115	4.6										1		4.55	0.05	NO	
Gym Teacher's Office	office	105	4.2										1		4.55	-0.35	YES	
Gym Teacher's - Toilet	toilet	29	1.16	1											3.66	-2.50	YES	
Gym Teacher's Office	office	75	3											1	5.55	-2.55	YES	
Gym Teacher's - Toilet	toilet	29	1.16	1											3.66	-2.50	YES	
Gym Teacher's Storage	storage	24	0.96												0.00	0.96	NO	
Lobby	common	93	3.72												0.00	3.72	NO	
Gymnasium	Gym	6223	248.92												0.00	248.92	NO	

Window Type	Width	Hieght	Projection	Venting
A - Awning	12	19	17	3.66
B - Awning	43	16.5	17	7.02
C - Hopper	42	23.5	18	8.19
D - Hopper	26	17	12	3.58
E - Hopper	26	23	17.5	5.95
F - Hopper	13	19	14	3.11
G - Hopper	16	18.5	19.5	4.67
H - Hopper	36	18.5	19.5	7.38
J - Hopper	32	27.5	20	8.26
K - Awning	18	20.5	17	4.55
L - Awning	26.5	20.5	17	5.55

Room Color Key	
(green)	Rooms that meet or exceed the minimum code required ventilation
(yellow)	Rooms that do not meet the code required ventilation, but have operable windows.
(red)	Rooms that do not have operable windows (either fixed or none present)

May Street School - First & Second Floor

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	A 3.19 AWNING	B 11.00 HOPPER	C 11.50 HOPPER	D 4.56 HOPPER	E 8.17 HOPPER	F 11.50 HOPPER	G 9.83 HOPPER	H 10.50 HOPPER	J 2.84 HOPPER	K 7.19 HOPPER	Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
First Floor																	
Room 01	classroom	787	31.48			6								69.00	-37.52	YES	
Room 02	classroom	778	31.12				5							22.81	8.31	NO	
Room 03	classroom	787	31.48				5							22.81	8.67	NO	
Room 04	classroom	785	31.4		6									66.00	-34.60	YES	
Girl's Showers	gym	218	8.72	2										6.39	2.33	NO	
Girl's Showers - Entry	gym	32	1.28											0.00	1.28	NO	
Girl's Shower - Room A	gym	139	5.56											0.00	5.56	NO	
Boy's Shower Room	gym	89	3.56	2										6.39	-2.83	YES	
Boy's Shower Room B	gym	180	7.2	2										6.39	0.81	NO	
Boy's Room + Vestibule	toilet	325	13			1								11.50	1.50	NO	
Room 05	classroom	776	31.04				5							22.81	8.23	NO	
Room 06	classroom	776	31.04				5							22.81	8.23	NO	
Main Office	office	225	9					2	1					27.83	-18.83	YES	
Girl's Room + Vestibule	toilet	256	10.24			1				1				21.33	-11.09	YES	
Room 07	classroom	1046	41.84			6					2			90.00	-48.16	YES	
Room 07 - Toilet	toilet	62	2.48									2		5.69	-3.21	YES	
Second Floor																	
Room 08	classroom	802	32.08			6								69.00	-36.92	YES	
Room 09	classroom	802	32.08				5							22.81	9.27	NO	
Principal's Office	office	257	10.28										1	7.19	3.09	NO	
Room 10	classroom	777	31.08				5							22.81	8.27	NO	
Room 11	classroom	774	30.96		6									66.00	-35.04	YES	
Storage	storage	46	1.84											0.00	1.84	NO	
Storage	storage	75	3											0.00	3.00	NO	
Boy's Room + Vestibule	toilet	320	12.8			1								11.50	1.30	NO	
Boy's Room - Custodian	support	42	1.68											0.00	1.68	NO	
Room 12	classroom	775	31				5							22.81	8.19	NO	
Room 13	classroom	775	31				5							22.81	8.19	NO	
Secretary Office	office	168	6.72											0.00	6.72	NO	
Nurse's Office	office	84	3.36					1	1					19.67	-16.31	YES	
Nurse's Toilet	toilet	24	0.96					1						8.17	-7.21	YES	
Girl's Room + Vestibule	toilet	257	10.28			1				1				21.33	-11.05	YES	
Room 14	classroom	793	31.72			6								69.00	-37.28	YES	
Room 14 - Toilet A	toilet	36	1.44			1								11.50	-10.06	YES	
Room 14 - Toilet B	toilet	36	1.44			1								11.50	-10.06	YES	

Window Type	Width	Hieght	Projection	Venting
A - Awning	32	14	10	3.19
B - Hopper	33	33	24	11.00
C - Hopper	36	33	24	11.50
D - Hopper	40	33	9	4.56
E - Hopper	16	33	24	8.17
F - Hopper	36	33	24	11.50
G - Hopper	26	33	24	9.83
H - Hopper	30	33	24	10.50
J - Hopper	12.5	19	13	2.84
K - Awning	32.5	25	18	7.19

Room Color Key	
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