Worcester Public Schools

Ventilation Assessment
&
COVID-19
Mitigation Strategies

for

Elm Park Community 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:

Elm Park Community School:
Elm Park Community School is located in the Doherty Quadrant of the Worcester at 23 North Ashland Street. The school was built in 1971, houses grades PK-06, has 28 classrooms and the building is 66,651 square feet. The original windows were replaced in 2018.

C. Table of Contents:

1) Mechanical Ventilation Report

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

This report briefly describes the existing ventilation systems at the Elm Park 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. For enhanced measures, WPS has begun to incorporate Bipolar Ionization (see ECCM-#3) extensively throughout the Elm Park 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.

Most of the HVAC systems supporting the Elm Park School appear capable of implementing this measure.

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.

Per the original design drawings many of the HVAC systems supporting the Elm Park School are supplying well below the 3 ACH requirement, however, many do appear capable of increasing outdoor air subject to outdoor ambient conditions and equipment limitations.

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

A majority of the main air handling systems in the building may be capable of supporting improved filtration up to MERV 13 pending testing of the system fan capacity. However, if higher filtration is desired systems must be tested and adjusted to accommodate the pressure drop associated with the increased filter efficiency. In addition, more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

The health center packaged rooftop unit and the several classroom unit ventilators are not capable of supporting increased filtration above MERV 8.

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 could be used in select areas and rooms to help clean the air within the room. These can be especially helpful where rooms have low outdoor air changes per hour and cannot be supplied with additional outdoor air or improved system ventilation.

ECCM #2: UV-C Light Sterilization - UV-C lights could be considered for insertion in equipment and ductwork to help neutralize viruses when 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 Elm Park 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 Elm Park School comply with current ventilation codes 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 Elm Park School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
General Classrooms	Multizone HV Air Handler	CCM - #1, #2 & #3 ECCM - #1 or #3 (*see note below)
Art Classrooms	Multizone HV Air Handler	CCM - #1 & #2 (+ ERV or dedicated exhaust) ECCM - #3
Gymnasium	HV Air Handlers	CCM - #1, #2 & #3 ECCM - #3
Admin. & Guidance Office	HV Air Handler	CCM - #1, #2 & #3 ECCM - #1 or #3 (*see note below)
Health Center	Packaged Rooftop HVAC Unit	CCM - #1 & #2 ECCM - #1 or #3 (*see note below)

**Note*: *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 / 1.2) 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:

A majority of the classrooms in the building are heated, ventilated and cooled via multiple heating and ventilation (HV) air handling units located in mechanical rooms. Several of the units are of the hot deck cold deck type with zone dampers at the unit. The units consist of a mixing chamber, filter section, hot water coil, supply and return fans. Hot water is fed to all these units from the building's central boiler plant. All the air handling units are fitted with 2" thick air filters all with an estimated efficiency of MERV 8.

These air handling systems are older however, may be capable of supporting increased filtration up to a maximum of MERV 13 (see CCM-#3) subject to testing. Systems must be tested and adjusted to accommodate the added pressure drop associated with this increased filter efficiency. In addition, more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

Each of the classroom air handlers deliver conditioned air to the classroom and associated spaces via a ducted supply air and return air system. For the multi-zone systems, each space is served from a dedicated supply duct from the multi-zone unit. Each zone of the multi-zone system has a damper with operator for control of the temperature of air by blending hot deck and cold deck air to each space. A DDC space thermostat controls the operation of the dampers and associated HV units.

For a standard classroom, current code would require 10 CFM per person of outside air plus 0.12 CFM per SF. The zone air distribution effectiveness for most of the classrooms is 0.8 with the lower factor due to the presence of ceiling supply and return terminals coupled with air that may be warmer than 15°F above space temperature in certain areas such as those spaces with greater thermal heat loss. As such, an average classroom of 850 SF with 26 occupants (25 students + 1 teacher) would require 453 CFM inclusive of the 0.8 correction or 362 CFM with the 1.0 factor.

A majority of the AHU systems supporting the classrooms introduce just under 17% outside air, per the original design drawings. Hence for a classroom with 840 CFM of supply air, the amount of outdoor air supplied to the room would be 140 CFM. This amount is well below the current code required outdoor air of 362 CFM to 453 CFM depending on space air distribution effectiveness. However, per the control drawings the main classroom systems have CO_2 reset control which appears configured to increase outdoor air levels above 17% when space CO_2 and associated occupancy require it.

Current EMS control drawings reflect a demand ventilation reset of OA based on return air CO_2. This is an effective approach if a CO_2 sensor was in each room or space served however, being in a common return, is not a good indication of proper outdoor air for a multi-zone system. This is due to the fact that the common return does not reflect the zone with maximum occupant demand as it is measuring a blend of air from all zones. Therefore zones with lighter occupant zones can dilute the overall CO_2 reading causing the controls to reduce outside for the entire system thereby impacting all zones including ones that may require more outside air due to elevated occupancy.

During pandemic conditions we recommend any demand ventilation reset schemes that would lower outdoor air levels be adjusted to ensure increased outdoor air to the spaces is maintained.

<u>Science & Art Rooms</u>:

There are no designated science rooms however, there is an art room which is supported by a single classroom unit ventilator. The current art room is approx. 1,300 SF in size and is supplied with 1,300 CFM of supply air of which 600 CFM is outdoor air. There is space exhaust listed at 540 CFM.

Per the current code, art rooms require higher ventilation levels than general use classrooms at 0.7 CFM/SF of exhaust. It appears the ventilation levels to this area does not comply with the exhaust air requirements nor the required make-up air. Additional exhaust and make-up air may be required for this space.

<u>Gymnasium & Cafeteria</u>:

The gymnasium and cafeteria spaces are supplied with air from multiple single zone style HV air handlers located in mechanical rooms. The air handlers are mixed air units which introduces a percentage of outside air into the recirculating air stream. Each unit has mixing dampers, angle filter box, hot water heating coil and a fan section. Relief air from the gymnasium space is accomplished via two (2) locker room HV units which take air from the gymnasium to feed the locker room make-up air needs. Relief air from the cafeteria/all-purpose space is accomplished via roof mounted centrifugal exhaust fans. The air handling units have 2" pleated filters with an estimated MERV rating of 8.

These air handling systems do not appear capable of supporting increased filtration much above MERV 8. However, the systems could be tested to verify if they could accommodate the added pressure drop associated with this increased filter efficiency. If higher filtration is applied more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

The gymnasium ventilation needs are based on a percentage of play area and spectator area. Play area requires an outdoor air volume of 0.3 CFM per SF whereas the spectator area requires 7.5 CFM per person plus 0.06 CFM per SF. The zone air distribution effectiveness is 1.0 based on ceiling supply and floor returns. With actual spectator area unknown, presuming the entire gym is play area, would yield a required outdoor air rate of 2,480 CFM.

Per the control drawings each unit's minimum outside air is 25% of the design supply volume which would equate to 6,200 CFM for the gymnasium space. Although the spectator occupancy and area must be verified, it appears the gymnasium space would be capable of accommodate quite a few occupants at these rates. The control drawings do reflect occupancy sensors in both these areas which can enable and disable the systems when no occupancy is sensed. This feature should be disabled during pandemic conditions to allow for pre-occupancy and post-occupancy purge ventilation of the space (see CCM #1).

Offices:

The offices are supported by a dedicated single zone central HV air handling unit. This air handler is a mixed air unit which introduces a percentage of outside air into the recirculating air stream. The unit has mixing dampers, angle filter box, hot water heating coil and a fan section. The air handling units have 2" pleated filters with an estimated MERV rating of 8.

The air handling system does not appear capable of supporting increased filtration much above MERV 8. However, the systems could be tested to verify if they could accommodate the added pressure drop associated with this increased filter efficiency. If higher filtration is applied more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

According to the control drawings the outdoor on this system is 39% or 600 CFM of the 1,530 CFM. The outdoor air requirements for office spaces tend to be lower than that of classrooms as densities are far lower. Although this is a fairly high percentage, the system may have the ability to support higher outdoor air rates. During these pandemic conditions, we recommend OA levels be increased subject to outdoor conditions and the equipment's capability.

Health Center:

The health center is supported by a 4-ton packaged cooling and heating rooftop unit (RTU). This unit is not original to the building and there are no existing plans to assess the original design ventilation rates. The unit is fitted with an outdoor air intake for introduction of some outdoor air. The control drawings do not reflect this RTU system, so we suspect the unit's control is limited to a local thermostat only. Although a sequence is not indicated, typically, during occupied periods, the unit fan would be configured to run continuous to provide space ventilation and thew unit would stage either cooling or heating along with mixing dampers to maintain space temperature setpoint. During unoccupied periods, the fans cycle off and only cycle on as needed for heating or cooling. Control sequence should be verified to insure continuous ventilation during occupied periods.

The packaged unit has limited in fan capacity and as such will not support filters in excess of MERV 8.

Controls:

Most of the major HVAC systems supporting the school are controlled by a building energy management system (EMS). The EMS system is currently supported by Alerton as represented by ABS.

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.

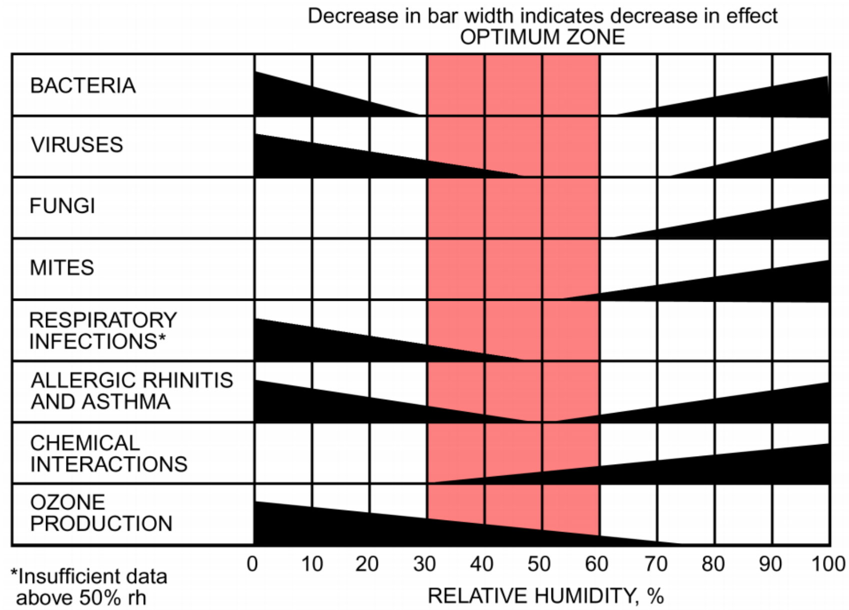

Fig. 1 Optimum Humidity Range for Human Comfort and Health
(Adapted from Sterling et al. 1985)

The Elm Park 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 Elm Park School, often have poor vapor barriers. 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 Elm Park School have an outdoor air exchange rate well below 3 not meeting the bare minimum criteria. However, many of the systems have the ability to introduce more outside air. 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 and therefore is not under ventilated. 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.

Elem Park School IAQ Sampling Summary

Space Tested	Temp. °F	Humidity % RH	CO2 %	TVOC ppm	HCHO ppm	Room Area SqFt	Room Ht. Ft	Volume Cubic Feet	Original Design OA CFM	Original OA Air ACH	Notes
1st Floor											
Music Room 101	71.7	34.7	497	0.78	0.01	1188	8.58	10193	190	1.1	
Common Area 100's	71.6	35.3	504	0.75	0.09	781	8.58	6701	None	N/A	
Classroom 121 & 123	71.3	34.8	544	0.97	0.1	1140	8.66	9872	333	2	
I.T Department 128	71.7	34.6	549	0.4	0.1	528	8.66	4572	167	2.2	
Preschool 1H	71.3	37.4	486	1.3	0.06	1316	8.91	11726	600	3.1	
Art Room 139	71.6	34.7	486	1.31	0.06	1341	8.83	11841	600	3	
2nd Floor											
Classroom 215	71.1	37.7	550	1.01	0.11	848	8.58	7276	140	1.2	
Common Area 200's	70.7	38.5	572	0.95	0	779	8.58	6684	None	N/A	
Lobby	70.4	36	574	1.69	0.09	1687	12	20244	213	0.6	
Library 219	70.2	35.6	576	1.12	0.12	2490	12	29880	780	1.6	
All Purpose Room 22	70.7	35.2	571	1.48	0.1	2265	12	27180	806	1.8	
General Office	70.1	38.8	608	1.21	0.12	515	8.75	4506	235	3.1	
Health Center	70.2	39.5	562		0.09	420	10	4200	na	N/A	
Lobby				1.13							
Gym	69.4	37.1	567	1.18	0.09	8283	21	173943	6200	2.1	
Level 3											
Classroom 311	72.9	34.6	501	0.91	0.06	848	8.66	7344	140	1.1	
Classroom 315	72.3	35	543	0.94	0.03	848	8.66	7344	140	1.1	

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.*

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.

Elm Park School 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	113/115/212/215/216/218/312/315/316/318	8160	1360	16.7	(4) 20x25x2 (6) 16x25x2	8	na	#1, #2, #3	#1, #3	a, b, c
AHU-2	103/108/112/205/209/211/305/310/311	6140	1027	16.7	(4) 20x25x2 (6) 16x25x2	8	na	#1, #2, #3	#1, #3	a, b, c
AHU-3	101/102/201/202/203/208/301/302/303/308	7,620	1,270	16.7	(2) 20x25x2 (3) 16x25x2	8	na	#1, #2, #3	#1, #3	a, b, c
AHU-4	219/220/221	4,330	870	20.1	na	na	na	#1, #2, #3	#3	a, b
AHU-5	219-LIBRARY	4425	885	20	na	na	na	#1, #2, #3	#3	b
AHU-6	222/223/228	4480	860	19.2	na	na	na	#1, #2, #3	#3	a, b
AHU-7	116/117/118/121/122/123	4050	1000	24.7	(4) 16x20x2 (2) 20x25x2	8	na	#1, #2, #3	#1, #3	a, b, c
AHU-8	224/225/226/227	2400	600	25	na	na	na	#1, #2, #3	#1, #3	a, b
AHU-9	231/232/234/237/238/241/245/248/252	1530	600	39.2	na	na	na	#1, #2, #3	#1, #3	a, b
AHU-10	266-GYM	6200	3100	50	na	na	na	#1, #2, #3	#3	b
AHU-11	266-GYM	6200	3100	50	na	na	na	#1, #2, #3	#3	b
AHU-12	260/261/262/265/268	1800	1800	100	na	na	na	#1	#3	a, b
AHU-13	253/255/256/263/264/267	1800	1800	100	na	na	na	#1	#3	a, b
AHU-14	COURT	4000	1000	25	na	na	na	#1, #2, #3	#1, #3	b
AHU-15	127	1400	1400	100	na	na	na	#1, #2, #3	#1, #3	a, b
CRUV-1	134-PRESCHOOL 1H	1300	600	46	na	na	na	#1, #2	#1, #3	a
CRUV-2	139-ART ROOM	1300	600	46	na	na	na	#1, #2	#1, #3	a
RTU Unit	Health Center	1600 est.	N/A	N/A	na	8	na	#1, #2	#1, #3	a

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.*

b. *Improved filter efficiency up to MERV 13 is dependent on the air handler's ability to support such. If higher filtration is desired, systems must be tested and adjusted to accommodate the pressure drop associated with the increased filter efficiency. In addition, more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.*

c. *Disable any CO_2 demand ventilation reset or occupancy sensor-based system shutdown (during scheduled occupied periods) during pandemic conditions.*

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 Elm Park 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.

Most of the HVAC systems supporting the Elm Park School appear capable of implementing this measure.

<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.

Most of the HVAC systems supporting the Elm Park School appear capable of implementing this measure subject to outdoor ambient conditions and equipment limitations.

CCM #3 – Improved Filtration

Improve filtration to up to MERV-13 on air handling systems, especially those which recirculate air. In addition, if possible, as filters are replaced provide sealant or gasketing between and/or around filters to reduced air bypass around filter sections. 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.

A majority of the main air handling systems in the building appear to be capable of supporting increased filtration up to a maximum of MERV 13. Systems must be tested and adjusted to accommodate the pressure drop associated with the increased filter efficiency. In addition, more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

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 and rooms to help clean the air within the room. 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. 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: Bipolar 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 Elm Park Schools case they could be installed in the supply air duct of the respective mixed air handling systems. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Elm Park School to address the current pandemic condition.

Air ionizers appear to be showing quite a bit of promise for low system impact in retrofit application. 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 the 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 in facilities such as convention centers, 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

Elm Park Elementary School

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	Number of Windows by Type																Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
				A AWNING	1.33	B AWNING	2.25	C AWNING	2.50	D HOPPER	2.75	E HOPPER	2.00	F AWNING	2.00	A1 HOPPER	1.67	B1 HOPPER	2.67				
First Floor																							
Garage / Patio	open	5314	212.56																	0.00	212.56	NO	
Team Meeting - 127	classroom	182	7.28																	0.00	7.28	NO	
Map Area	common	5022	200.88																	0.00	200.88	NO	
Art Room - 139	classroom	1340	53.6						3											7.50	46.10	NO	
Art Room Storage	storage	175	7																	0.00	7.00	NO	
Preschool - 1H - 1	classroom	548	21.92																	0.00	21.92	NO	
Preschool - 1H - 2	classroom	488	19.52						4											10.00	9.52	NO	
Kindergarten Step 1 H	classroom	280	11.2																	0.00	11.20	NO	
Preschool - 1H - Storage	storage	168	6.72																	0.00	6.72	NO	
E.S.L. - 124	classroom	306	12.24																	0.00	12.24	NO	
Storage - 126	storage	217	8.68																	0.00	8.68	NO	
Adj. Counselor - 1M - 120	office	271	10.84																	0.00	10.84	NO	
Stabilizaiton - 119	office	286	11.44																	0.00	11.44	NO	
Classroom - 1L	classroom	1140	45.6																	0.00	45.60	NO	
Classroom - 1L - R.T.I.	office	140	5.6																	0.00	5.60	NO	
Classroom - 1K - 123 / 121	classroom	1139	45.56																	0.00	45.56	NO	
Classroom - 1K - RTI	office	140	5.6																	0.00	5.60	NO	
Boys Room	toilet	131	5.24																	0.00	5.24	NO	
Girls Room	toilet	131	5.24																	0.00	5.24	NO	
Men's Room	toilet	33	1.32																	0.00	1.32	NO	
Women's Room	toilet	33	1.32																	0.00	1.32	NO	
Science Lab - 128	classroom	527	21.08										3							6.00	15.08	NO	
Information Technology - 1A - 113A	classroom	870	34.8																	0.00	34.80	NO	
Storage - 107	storage	80	3.2																	0.00	3.20	NO	
Computer Lab - 1G - 101	classroom	1187	47.48														1			1.67	45.81	NO	
L.D. Office - 106	office	142	5.68																	0.00	5.68	NO	
R.T.I Space	office	131	5.24																2	5.33	-0.09	YES	
Classroom - 1F - 101	classroom	892	35.68														1			1.67	34.01	NO	
Kindergarten - 1E - 103	classroom	805	32.2														1			1.67	30.53	NO	
Shared Toilet	toilet	91	3.64																	0.00	3.64	NO	
R.T.I Space	office	131	5.24																2	5.33	-0.09	YES	
Kindergarten - 1D - 112	classroom	805	32.2														1			1.67	30.53	NO	
Kindergarten - 1C - 112A	classroom	835	33.4														1			1.67	31.73	NO	
Shared Toilet	toilet	91	3.64																	0.00	3.64	NO	
R.T.I Space	office	131	5.24																2	5.33	-0.09	YES	
Classroom - 1B - 113	toilet	1000	40														1			1.67	38.33	NO	
Common Area	common	781	31.24																	0.00	31.24	NO	
Staff Toilet	toilet	39	1.56																	0.00	1.56	NO	
Children Toilet	toilet	86	3.44																	0.00	3.44	NO	

Second Floor

Teachers's Lounge	support	476	19.04									0.00	19.04	NO
Book storage	storage	299	11.96									0.00	11.96	NO
Storage Room	storage	337	13.48									0.00	13.48	NO
Boys Toilet	toilet	259	10.36									0.00	10.36	NO
Gymnasium	gym	8283	331.32									0.00	331.32	NO
Girls Room	toilet	258	10.32									0.00	10.32	NO
Supply Room	storage	731	29.24									0.00	29.24	NO
Music - 259	classroom	509	20.36									0.00	20.36	NO
Speech - 254	classroom	112	4.48									0.00	4.48	NO
Shower Room	gym	87	3.48									0.00	3.48	NO
Storage - 256	storage	107	4.28									0.00	4.28	NO
Occupational Therapy - 257	classroom	257	10.28									0.00	10.28	NO
Gym Equipment - 256	gym	249	9.96									0.00	9.96	NO
Gym Office	office	110	4.4									0.00	4.40	NO
Helen A. Dowditch Health Lobby	lobby	420	16.8									0.00	16.80	NO
Nurse Office	office	93	3.72									0.00	3.72	NO
Exam 2	support	79	3.16									0.00	3.16	NO
Exam 3	support	89	3.56	1								1.33	2.23	NO
Exam 4	support	101	4.04	1								1.33	2.71	NO
Restroom	toilet	49	1.96									0.00	1.96	NO
Nurses Common Area	support	200	8									0.00	8.00	NO
General Office	office	514	20.56									0.00	20.56	NO
Conference Room - 240	conference	283	11.32									0.00	11.32	NO
Principal - 239	office	199	7.96	2								2.67	5.29	NO
Principal's Toilet Room	toilet	22	0.88									0.00	0.88	NO
Asst Principal - 238	office	145	5.8	2								2.67	3.13	NO
Psych - 233	office	98	3.92	1								1.33	2.59	NO
Lead Teacher - 230	office	98	3.92	1								1.33	2.59	NO
Curriculum - 235	office	92	3.68									0.00	3.68	NO
Break Room - 221	office	104	4.16									0.00	4.16	NO
File Room - 232	storage	97	3.88									0.00	3.88	NO
Server Room	storage	46	1.84									0.00	1.84	NO
Food Service - 228	café	367	14.68									0.00	14.68	NO
Food Storage - 229	storage	169	6.76									0.00	6.76	NO
All Purpose Room - 223 - A	conference	2265	90.6									0.00	90.60	NO
All Purpose Room - 223 - B	conference	2444	97.76						6			12.00	85.76	NO
Stage	stage	279	11.16									0.00	11.16	NO
Teacher's Resource / Library / Community Room - 219	support	2489	99.56						3			6.00	93.56	NO
Storage - 220	storage	362	14.48									0.00	14.48	NO
Counselors Office	office	97	3.88									0.00	3.88	NO
Cust. Office	office	103	4.12									0.00	4.12	NO
Lobby	lobby	1686	67.44									0.00	67.44	NO
Men's Room	toilet	154	6.16									0.00	6.16	NO
Women's Room	toilet	155	6.2									0.00	6.20	NO
Supply Room - 253	storage	104	4.16									0.00	4.16	NO
R.I.T. Room	office	72	2.88									0.00	2.88	NO
Cust - 271	support	38	1.52									0.00	1.52	NO
R.I.T. Room	office	167	6.68									0.00	6.68	NO
Classroom - 2A - 216	classroom	875	35									0.00	35.00	NO
Classroom - 2H - 208	classroom	873	34.92									0.00	34.92	NO
Classroom - 2G - 203	classroom	847	33.88							1		1.67	32.21	NO
R.I.T. Room	office	131	5.24								2	5.33	-0.09	YES
Classroom - 2F - 201	classroom	848	33.92							1		1.67	32.25	NO
Classroom - 2E - 205	classroom	847	33.88							1		1.67	32.21	NO
R.I.T. Room	office	131	5.24								2	5.33	-0.09	YES
Recovery Room - 2D - 211	classroom	847	33.88							1		1.67	32.21	NO
Classroom - 2C - 212	classroom	846	33.84							1		1.67	32.17	NO
R.I.T. Room	office	131	5.24								2	5.33	-0.09	YES
Classroom - 2B - 215	classroom	875	35							1		1.67	33.33	NO
Common Area	common	779	31.16									0.00	31.16	NO
Girl's Room	toilet	135	5.4									0.00	5.40	NO
H/C Toilet	toilet	42	1.68									0.00	1.68	NO
Boy's Room	toilet	135	5.4									0.00	5.40	NO
H/C Toilet	toilet	42	1.68									0.00	1.68	NO

Third Floor																							
	Classroom - 3A - 316	classroom	875	35																	0.00	35.00	NO
	Classroom - 3H - 308	classroom	875	35																	0.00	35.00	NO
	Classroom - 3G - 303	classroom	848	33.92														1			1.67	32.25	NO
	R.I.T. Room	office	131	5.24																2	5.33	-0.09	YES
	Classroom - 3F - 301	classroom	847	33.88														1			1.67	32.21	NO
	Classroom - 3E - 305	classroom	847	33.88														1			1.67	32.21	NO
	R.I.T. Room	office	131	5.24																2	5.33	-0.09	YES
	Classroom - 3D - 311	classroom	847	33.88														1			1.67	32.21	NO
	Classroom - 3C - 312	classroom	847	33.88														1			1.67	32.21	NO
	R.I.T. Room	office	131	5.24																2	5.33	-0.09	YES
	Classroom - 3B - 315	classroom	848	33.92														1			1.67	32.25	NO

Window Type	Width	Hieght	Projection	Venting
A - Awning	18	14	6	1.33
B - Awning	40	14	6	2.25
C - Awning	18	42	6	2.50
D - Hopper	48	18	6	2.75
E - Hopper	30	18	6	2.00
F - Awning	30	18	6	2.00
A1 - Hopper	21	19	6	1.67
B1 - Hopper	45	19	6	2.67

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)