

Worcester Public Schools

Ventilation Assessment & COVID-19 Mitigation Strategies

for

Union Hill Elementary School Worcester, MA



January 31, 2021

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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 or 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:

Union Hill Elementary School:

The Union Hill Elementary School is located in the North Quadrant of Worcester at 1 Chapin Street. The school was built in 1890, houses grades PK-06, has 21 classrooms and the building is 46,295 square feet. The windows in this building were replaced in 2014.

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1) Mechanical Ventilation Report

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I. EXECUTIVE SUMMARY

This report briefly describes the existing ventilation systems at the Union Hill 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), CO₂ (carbon dioxide in ppm), CH₂O (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 Union Hill 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. Those areas served by classroom unit ventilators as well as the All-Purpose Room AHU unit, appear to be 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.

The building has a mix of HVAC system types. Those areas served by classroom unit ventilators as well as the All-Purpose Room AHU unit, appear to be capable of implementing this measure.

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 All-Purpose Room may not be capable of supporting increased filter efficiency over MERV 8 pending testing. 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 Union Hill 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 Union Hill 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 Union Hill School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
All-Purpose Room	AHU-1	CCM - #1 & #2 ECCM - #3
General Classrooms Bldg. #1	Gravity Vent Shafts	ECCM - #1 & #3 (*see note below) Provide outdoor air ventilation.
General Classrooms Bldg. #2	Unit Ventilators	CCM - #1 & #2 ECCM - #3
Offices	None	ECCM - #1 or #3 (*see note below) Provide outdoor air ventilation.

**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. Regardless, we highly recommend outdoor air of some level be provided in areas without ventilation systems, even if via windows as there is no substitute for proper ventilation.*

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)
- CO₂ (carbon dioxide in ppm)
- CH₂O (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 CO₂ levels were low since space CO₂ 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:

<u>Distribution Configuration</u>	<u>ZDE</u>
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 identified on control drawings. The rooms with UV's are fitted with air 1" thick filters with an estimated MERV rating of 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 (located in building #2) 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 heating 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 500 CFM of outdoor air being introduced to classrooms through the unit ventilator system.

The operation of the ducted shaft ventilation system serving building #1 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. The intake for this system has been boarded over.

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 850 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 centrifugal exhaust fans of unknown capacity.

All-Purpose Room:

The all-purpose room is supported by a one (1) mixed style air handling unit. The volume of outdoor air the system moves is unknown however, the control drawings reflect a normal minimum outdoor air percentage of 15% of the unit's design supply airflow capacity.

For a multi-use assembly space, current code would require 7.5 CFM per person of outside air plus 0.06 CFM per SF. For a system with a presumed zone air distribution effectiveness of 0.8, a room size of 2276 SF with 100 occupants would require 1,108 CFM of outdoor air. As such, for the AHU system would need to introduce more outside air to support that occupant load. Testing and Balancing of these and other systems, would be required to confirm outdoor airflow rates

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 rooms and one art room 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. If the art room is to be used as such additional dedicated exhaust and associated make-up air would be required.

Offices:

The office areas do not appear to have any ventilation systems except that which is provided via operable windows, a thru wall air conditioner and/or local exhaust from adjoining bathrooms. Although some thru wall air conditioners can introduce some outdoor air it is not operated year-round. Positive air ventilation should be provided in these areas.

Controls:

Controls in the building appear to be fairly comprehensive. From the control drawings it appears the building energy management system (EMS) controls the unit ventilators and the All-Purpose Room AHU unit. There are existing pneumatic controls on the UV 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)
- CO₂ (carbon dioxide in ppm)
- CH₂O (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 CO₂ levels were low since space CO₂ 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.

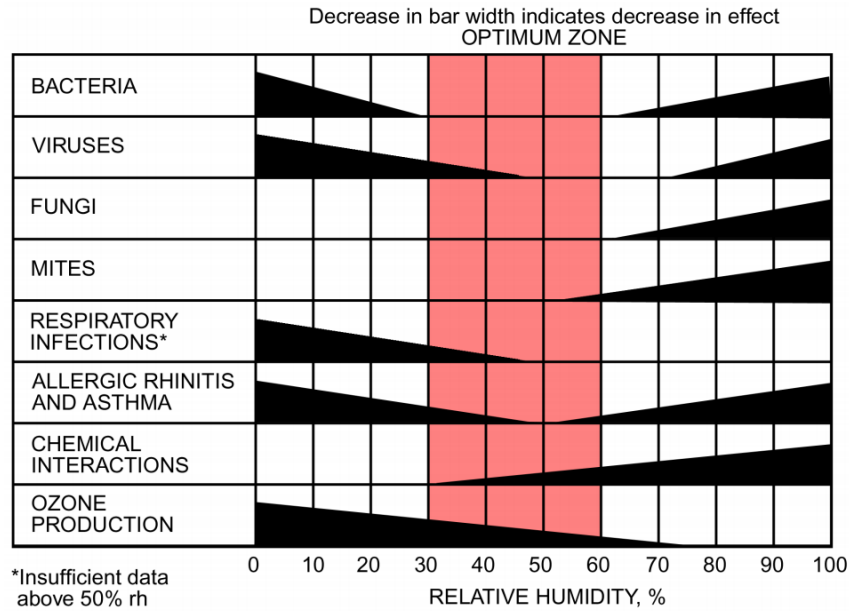


Fig. 1 Optimum Humidity Range for Human Comfort and Health
 (Adapted from Sterling et al. 1985)

The Union Hill 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 Union Hill 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 Union Hill School supported by unit ventilators appear to have a design outdoor air exchange rate of 3 or above. Rooms without UV’s are presumed to have an ACH below 3. 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 than what this document considers the bare minimum outdoor air exchange rate may meet or exceed the most current ventilation standards dependent on the space 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.

Union Hill Elem. School IAQ Sampling Summary											
Space Tested	Temp. °F	Humidity % RH	CO2 %	TVOC ppm	HCHO ppm	Room Area SqFt	Room Ht. Ft	Volume Cubic Feet	Design OA CFM	OA Air ACH	Notes
Building "1" Basement Floor											
Art Room B03	66.2	33.6	477	1.33	0.18	796	9.5	7562	0	0	
Building "1" First Floor											
Classroom 104	67	39.2	508	1.35	0.14	836	12.41	10375	0	0	
Teacher Workroom 105	69.7	32	488	1.3	0.19	317	12.66	4013	0	0	
Building "1" Second Floor											
Classroom 202	74.9	36.9	494	1.36	0.19	842	12	10104	0	0	
Office 207	74.2	37.2	483	1.36	0.21	100	12.25	1225	0	0	
Classroom 204	72.8	28.3	472	1.37	0.18	835	11.58	9669	0	0	
Building "2" Ground Floor											
Main Office	70.8	29	502	1.6	0.26	158	9	1422	0	0	
All Purpose Room	71.2	27.7	492	1.5	0.25	2276	14.75	33571	654	1.2	
Room 3	71.9	30.2	497	1.41	0.2	923	9	8307	500	3.6	
Room 4	70	29.4	491	1.44	0.19	924	9.08	8390	500	3.6	
Nurse	72.4	27.4	490	1.37	0.19	425	9.33	3965	N/A	N/A	
Computer Room	72.2	27.9	480	1.45	0.2	529	9.33	4936	N/A	N/A	
Room 8	72.6	25.6	493	1.34	0.18	846	8.83	7470	500	4	
Room 10	73	25.2	485	1.34	0.19	850	9	7650	500	3.9	

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.

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.

Union Hill Ventilation System Summary										
Unit ID	Area Served	Exist. Supply	Exist. O.A.	Exist. O.A.	Exist. Filter Qty & Size	Exist. Filter MERV Rating	Exist. Filter Vel. (FPM)	Proposed CCM #	Proposed ECCM #	Notes
AHU-1	All Purpose Room	4360	654	15%	N/A	8	417	#1, #2	#3	a
Misc. UV's	Classrooms Bldg. #2	1000	500	50%	varies	8	N/A	#1, #2	#1, #3	a
Vent Shaft	Classrooms Bldg. #1	N/A	N/A	N/A	N/A	N/A	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 Union Hill 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.

CCM #1 – 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. Those areas served by classroom unit ventilators as well as the All-Purpose Room AHU unit, appear to be capable of implementing this measure

CCM #2 – Increased Ventilation

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., CO2 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. Those areas served by classroom unit ventilators as well as the All-Purpose Room AHU unit, appear to be capable of implementing this measure.

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.

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 All-Purpose Room is old and may not be capable of supporting increased filter efficiency 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 Union Hill 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 Union Hill 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

Union Hill Elementary School - Building 1

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	0.83	B	3.54				
Basement Level											
Room B02 - Custodial Office	office	618	24.72					0.00	24.72	NO	
Room B03 - Art Room	classroom	769	30.76				4	14.17	16.59	NO	
Room B05	storage	77	3.08					0.00	3.08	NO	
Room 07 - Girl's Room	toilet	510	20.4					0.00	20.40	NO	
Room B07A	storage	126	5.04					0.00	5.04	NO	
Room B08 - Boy's Room	toilet	444	17.76					0.00	17.76	NO	
Room B08A	storage	310	12.4					0.00	12.40	NO	
Room B09	storage	32	1.28					0.00	1.28	NO	
Room B10 (multiple spaces)	storage	317	12.68					0.00	12.68	NO	
First Floor											
Room 100S	storage	54	2.16					0.00	2.16	NO	
Room 100T - Toilet	toilet	34	1.36					0.00	1.36	NO	
Room 101	classroom	866	34.64		8			6.67	27.97	NO	
Room 101 - Wardrobe	support	122	4.88					0.00	4.88	NO	
Room 102	classroom	845	33.8		6			5.00	28.80	NO	
Room 103	classroom	843	33.72		6			5.00	28.72	NO	
Room 103W - Wardrobe	support	91	3.64					0.00	3.64	NO	
Room 104	classroom	836	33.44		8			6.67	26.77	NO	
Room 104W - Wardrobe	support	151	6.04		1			0.83	5.21	NO	
Room 105 - Teacher Break / Workroom	support	317	12.68		1			0.83	11.85	NO	
Room 106 - Spec Edu	classroom	100	4					0.00	4.00	NO	
Room 107 - Staff Toilet	toilet	111	4.44		1			0.83	3.61	NO	
Second Floor											
Room 200S	storage	54	2.16					0.00	2.16	NO	
Room 201	classroom	866	34.64		8			6.67	27.97	NO	
Room 201W - Wardrobe	support	154	6.16					0.00	6.16	NO	
Room 202	classroom	842	33.68		6			5.00	28.68	NO	
Room 203	classroom	841	33.64		6			5.00	28.64	NO	
Room 203 - Closet	storage	30	1.2					0.00	1.20	NO	
Room 203W - Wardrobe	support	91	3.64					0.00	3.64	NO	
Room 204	classroom	835	33.4		8			6.67	26.73	NO	
Room 204W - Wardrobe	support	118	4.72					0.00	4.72	NO	
Room 205	office	60	2.4					0.00	2.40	NO	
Room 206 - Conf / Office	office	319	12.76		1			0.83	11.93	NO	
Room 207	office	100	4					0.00	4.00	NO	
Room 208	office	43	1.72					0.00	1.72	NO	
Room 209	office	111	4.44		1			0.83	3.61	NO	

Window Type	Width	Hieght	Projection	Venting
A - Double Hung	40	3	-	0.83
B - Hopper	41	44	6	3.54
** Window Type A could be adusted to open 42" **				

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

Union Hill Elementary School - Building 2

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 HOPPER 2.33	B HOPPER 1.94	C HOPPER 2.08	D HOPPER 2.78	E HOPPER 1.04	F HOPPER 2.64	G HOPPER 1.72	H HOPPER 2.34	J HOPPER 1.53								
Ground Floor																				
All Purpose Room	common	2276	91.04	5													11.63	79.41	NO	
All Purpose Room - File Room	storage	314	12.56														0.00	12.56	NO	
All Purpose Room - Classroom	classroom	309	12.36														0.00	12.36	NO	A/C unit on fixed window.
All Purpose Room - Office	office	373	14.92														0.00	14.92	NO	
Kitchen	kitchen	168	6.72														0.00	6.72	NO	
Kitchen Storage	storage	238	9.52														0.00	9.52	NO	
Office	office	70	2.8														0.00	2.80	NO	
Main Office	office	158	6.32				2										4.17	2.15	NO	A/C unit in one window Type-C.
Main Office - Common Area	office	337	13.48				4										8.33	5.15	NO	A/C unit in two window Type-C.
Men's Room	toilet	54	2.16														0.00	2.16	NO	
Women's Room	toilet	94	3.76														0.00	3.76	NO	
Storage	storage	20	0.8														0.00	0.80	NO	
Principal's Office	office	186	7.44				3										6.25	1.19	NO	A/C unit in one window Type-C.
Principal's Toilet	toilet	23	0.92				1										2.08	-1.16	YES	
Office	office	156	6.24			3											5.83	0.41	NO	A/C unit in one window Type-B.
Room 01A	classroom	688	27.52											1	2		6.41	21.11	NO	
Room 01A - Toilet	toilet	24	0.96														0.00	0.96	NO	
Room 01A - Toilet	toilet	24	0.96														0.00	0.96	NO	
Room 01A - Storage	storage	39	1.56														0.00	1.56	NO	
Room 01B	classroom	631	25.24											1	3		8.75	16.49	NO	
Room 02	classroom	924	36.96			2									2		9.17	27.79	NO	A/C unit on fixed window.
Shared Storage (2/3)	storage	26	1.04														0.00	1.04	NO	
Shared Toilet (2/3)	toilet	29	1.16														0.00	1.16	NO	
Shared Toilet (2/3)	toilet	29	1.16														0.00	1.16	NO	
Room 03	classroom	923	36.92			2									2		9.17	27.75	NO	A/C unit on fixed window.
Room 03 - Storage	storage	25	1														0.00	1.00	NO	
Room 04	classroom	924	36.96			2									2		9.17	27.79	NO	A/C unit on fixed window.
Room 04 - Storage	storage	27	1.08														0.00	1.08	NO	
Shared Storage (4/5)	storage	27	1.08														0.00	1.08	NO	
Shared Toilet (4/5)	toilet	30	1.2														0.00	1.20	NO	
Shared Toilet (4/5)	toilet	30	1.2														0.00	1.20	NO	
Room 05	classroom	942	37.68			2									2		9.17	28.51	NO	A/C unit on fixed window.
Nurses Office	support	217	8.68			1									2		7.22	1.46	NO	A/C unit on fixed window.
Nurses Office - Toilet	toilet	36	1.44														0.00	1.44	NO	
Nurses Office - Exam	support	109	4.36			1									1		4.58	-0.22	YES	
Nurses Office - Exam	support	99	3.96			1									1		4.58	-0.62	YES	
Nurses Office Exam Toilet	toilet	22	0.88														0.00	0.88	NO	
Nurses Office - Storage	storage	17	0.68														0.00	0.68	NO	
Storage	storage	104	4.16														0.00	4.16	NO	
Computer Room	classroom	529	21.16														0.00	21.16	NO	
Toilet Room (adj to boiler)	toilet	185	7.4														0.00	7.40	NO	
Room 06	classroom	846	33.84				2								2		9.72	24.12	NO	A/C unit on fixed window.
Room 07	classroom	845	33.8				2								2		9.72	24.08	NO	A/C unit on fixed window.
Room 08	classroom	846	33.84				2								2		9.72	24.12	NO	A/C unit on fixed window.
Room 09	classroom	856	34.24				2								2		9.72	24.52	NO	A/C unit on fixed window.
Room 10	classroom	850	34				2								2		9.72	24.28	NO	A/C unit on fixed window.
Room 11	classroom	846	33.84				2								2		9.72	24.12	NO	A/C unit on fixed window.
Girl's Room	toilet	196	7.84														0.00	7.84	NO	
Custodian	support	21	0.84														0.00	0.84	NO	
Boy's Room	toilet	217	8.68														0.00	8.68	NO	
Room 12	classroom	850	34				2								2		9.72	24.28	NO	A/C unit on fixed window.
Room 13	classroom	850	34				2								2		9.72	24.28	NO	A/C unit on fixed window.

Window Type	Width	Height	Projection	Venting
A - Hopper	41	26	5	2.33
B - Hopper	37	19	5	1.94
C - Hopper	41	19	5	2.08
D - Hopper	41	39	5	2.78
E - Hopper	30.5	24	2.75	1.04
F - Hopper	37	39	5	2.64
G - Hopper	36	19	4.5	1.72
H - Hopper	36	39	4.5	2.34
J - Hopper	18	26	5	1.53

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