

Worcester Public Schools

Ventilation Assessment & COVID-19 Mitigation Strategies

for

The Accelerated Learning Lab School “The All School” Claremont / Woodland 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 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:

The All School:

The All School is located in the South Quadrant of the Worcester at 15 Claremont Street and 93 Woodland Academy. The School was built in 1999, houses grades PK-12, has 50 classrooms and the building is 148,722 square feet. The widows are original to the 1999 construction.

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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 Claremont 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 Claremont 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 Claremont School are 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.

Many of the classroom HVAC systems supporting the school are delivering air that varies from less than to more than the 3 ACH requirement. A majority of the classrooms supported by unit ventilators as well as many other areas supported by air handlers (gymnasium, cafeteria etc....) have the ability to increase outdoor air (O.A.) for higher O.A. ventilation and air exchange rates, subject to outdoor ambient conditions and equipment limitations. Areas supported by fan coil units such as the administration offices cannot support this measure as their outside air duct system has been sized for minimum outside air only. Any CO2 demand ventilation reset controls should be adjusted during pandemic conditions to allow for elevated outdoor air levels regardless of occupancy.

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

Many of the air handling systems supporting the school may support increased filtration above MERV 8 up to a maximum of MERV 13 subject to testing of the respective fans. Unit ventilators and fan coil units cannot support filtration above MERV 8 either due to physical equipment limitations (i.e., fan coils limited to 1” filters) or fan capacity limitations. Increased filter 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 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 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 virus which becomes 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 viruses' ability to infect.

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

Space	Exist. O.A. Vent. Systems	Recommendations
General Classrooms	Unit Ventilators & Air Handlers	CCM - #1 & #2 (#3 for AHU's only) ECCM - #1 or #3 (*see note below)
Science and Art Classrooms	Unit Ventilators	If used as science lab and art rooms, increase O.A. ventilation to code minimum (may require system work). CCM - #1 & #2 ECCM - #1 or #3 (*see note below)
Gymnasium	Packaged Rooftop Units	CCM - #1 & #2 ECCM - #3
Cafeteria	Air Handler	CCM - #1 & #2 ECCM - #3
Office, etc....	Fan Coils	CCM - #1 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, and 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 and cooled with 2-pipe classroom unit ventilators. These units are fed with hot water and chilled water from a central boiler/chiller plant. Most of the units are fitted with air 1” thick filters with an estimated MERV rating of 7 or 8 which is typical for units of this type. These units can support a maximum filter efficiency of MERV 8.

The classroom unit ventilators are located along exterior walls with each having an outdoor air louver and associated control dampers to allow outdoor air to enter the classroom space through the unit ventilator. During occupied periods, the unit fans run continuous to provide space ventilation and electric operators modulate the hot/chilled water 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 water valve opening when there is a need for heating or cooling.

Although classrooms vary in size and airflow, for an average classroom size of 900 SF, the system delivers approx. 520 CFM of outdoor air to the classroom spaces via the unit ventilator. Where unit ventilators are present, exhaust is generally supported by roof exhaust fans connecting to the supporting rooms via above ceiling ductwork and vertical duct chases. The exhaust fans appear to exhaust the same quantity of minimum outside air for ventilation and are not sized to exhaust 100% outside air which occurs when the unit ventilators go into free cooling/economizer mode.

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 zone air distribution effectiveness of 1.0, as most classrooms with the current unit ventilator system are, a room size of 900 SF with 26 occupants (25 students + 1 teacher) would require 368 CFM of outdoor. Hence the current systems operating at approx. 520 CFM+/- provide more than the code required outdoor air to the rooms.

Offices and other spaces, not supported by either unit ventilators or air handlers, are supported by ducted fan coil units. These units incorporate filter racks with MERV 8 filters, chilled/hot water coils and supply fans. Outdoor air to these units is direct from outdoors via louvers and sized to support only that which was required for minimum outdoor air ventilation used during the design. These systems do not have the ability to support increased filtration efficiencies or much of an increase in the volume of outdoor air.

Bathroom and local exhaust requirements are supported by roof mounted centrifugal exhaust fans. These exhaust systems appear to meet or exceed the current ventilation codes for the spaces serviced.

Science & Art Rooms:

The science and art room areas are supported by the same types of unit ventilators and exhausts as the normal classroom systems. These rooms are each supplied with 520 CFM of outside air and with a near matching amount of exhaust air.

Per the current code, science rooms and art rooms require higher ventilation levels than general use classrooms with a driving factor being the 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. It appears the buildings ventilation levels for these rooms may be non-compliant, especially if they are used as art rooms or science labs with chemical use. If the rooms are not used as labs, lower typical classroom ventilation levels may apply.

Cafeteria:

Outdoor air for the two (2) cafeterias is supported by two (2) air handling unit, one for each space. The units are mixed air systems each configured with mixing dampers, filter sections, hot/chilled water coil and supply fan along with a remote return fan. The unit has 2" thick pleated filters with an estimated MERV rating of 8. The design drawings reflect a relatively low percentage of outdoor air at only 10% which would not comply with current ventilation code for a typical cafeteria occupancy. The units do, however, appear to have the capability to introduce more outdoor air.

This unit currently has MERV 8 filters and may be able to support improved filtration pending unit airflow testing to evaluate the unit's capabilities.

For a cafeteria space, current code would require 7.5 CFM per person of outside air plus 0.18 CFM per SF. One of the existing cafeterias, encompasses approx. 2,087 SF with 150 occupants would require 1,375 CFM of outside air, well above the current 200 CFM design OA.

Gymnasium:

The gymnasium is heated and ventilated through the use of two (2) roof packaged gas /electric rooftop HVAC units. The units each include a mixing box, exhaust fan, filter section, gas furnace, DX cooling coil with condensing section and a supply fan. The filters on both the units are 2" thick pleated filters with a MERV rating of 8. Due to the age, style, and condition of these units we do not anticipate the units can support a filter efficiency higher than MERV 8.

The original plans for the gymnasium reflect the two systems introducing a combined outside air volume of 5,000 CFM. The code requires 0.3 CFM per SF of outdoor air for play area coupled with a separate value for spectator area. As the bleachers were retracted during our visit, the spectator area capacity is unknown. However, if we presume the entire space as play area and use a zone air distribution effectiveness of 0.8, due to the high supply and return distribution, the required outdoor air volume for the 7,589 SF space is 2,845 CFM, within the design value of 5,000 CFM.

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 Automated Building Systems, Inc (ABS). Although a further review with the EMS vendor would be required to ascertain the extent of this system it is our current understanding that the system controls all the air handlers, unit ventilators and fan coil units.

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.

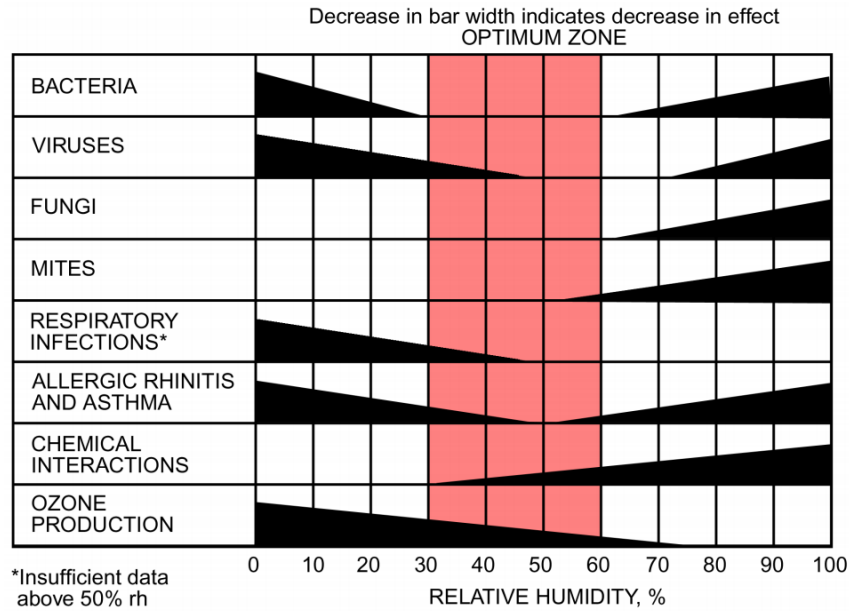


Fig. 1 Optimum Humidity Range for Human Comfort and Health
 (Adapted from Sterling et al. 1985)

The Claremont 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. Although newer structures, such as Claremont School often have a fair 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”. The general classrooms in the Claremont School have an outdoor air exchange rate which varies below and above the bare minimum criteria of 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 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.

ALL Claremont 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											
Parent W105	74.4	47.8	449	0.84	0.016	658	9	5922	520	5.3	
Adaptive Exercise W107	73.3	53.5	485	0.88	0.17	1557	9.18	14293	520	2.2	
Health Suite	74.3	45.1	400	0.66	0.1	1665	8	13320	N/A	N/A	
Teachers Loumge W108	75.1	55	439	0.66	0.11	843	9	7587	520	4.1	
Pre-Kindergarten W109	74	52.6	442	0.71	0.12	1006	9.25	9306	520	3.4	
Classroom W112	73.9	51.1	496	0.63	0.09	1213	9.41	11414	260	1.4	
Boy's Locker Rm W127	74.3	45.5	440	0.64	0.11	432	9	3888	100	1.5	
Admin W142	73.2	44.4	477	1.37	0.28	861	8.58	7387	N/A	N/A	
Lobby 141	71.1	66.1	472	0.8	0.19	1196	9.58	11458	800	4.2	
Cafeteria "B" 149	74.6	43.1	430	0.66	0.09	2087	9.41	19639	200	0.6	
Kitchen 153	73.5	45.2	502	0.68	0.09	2614	8.91	23291	N/A	N/A	
Classroom E178	74.1	52.9	426	0.64	0.09	900	9.41	8469	520	3.7	
Kiva E172	74.1	48.9	445	0.94	0.12	1028	9.33	9591	N/A	N/A	
Science E180	73.4	53.2	432	0.64	0.08	1169	9.5	11106	260	1.4	
Disc E181	73.6	48.9	428	1.32	0.1	801	9.5	7610	N/A	N/A	
Classroom E183	74.1	48.9	445	0.94	0.12	903	9.41	8497	520	3.7	
Research E194	73.9	52.7	423	0.54	0.09	1206	8.41	10142	N/A	N/A	
2nd Floor											
Classroom W208	74.1	53.8	448	0.72	0.12	888	9.41	8356	520	3.7	
Classroom W205A	74.1	49.7	455	0.63	0.08	510	9.41	4799	N/A	N/A	
Kindergarten W214	74.8	52.4	442	0.82	0.1	1146	9.25	10601	520	2.9	
Research W215	75	51.8	455	0.82	0.12	1128	9.25	10434	260	1.5	
"Back" Stage w216	74.6	51.2	471	0.68	0.11	686	9	6174	N/A	N/A	
Gym 246	75.2	49.3	423	0.57	0.09	7589	26.66	202323	5000	1.5	
Confernece E277	75.1	53	460	0.69	0.08	249	9.5	2366	N/A	N/A	
Classroom E278	75	53.9	436	0.79	0.1	941	9.5	8940	520	3.5	
Tech. Ed. E282	75	50.9	433	0.64	0.09	1130	9.5	10735	260	1.5	
Biology & Physics E284	75.3	49.1	433	1.03	0.09	1276	9.5	12122	520	2.6	
Music E297	74.3	46.1	427	0.95	0.11	1100	9.5	10450	N/A	N/A	
3rd Floor											
Classroom W307	72.3	60.3	486	1.44	0.14	938	9.41	8827	520	3.5	
Kiva W305	73.9	54.3	436	1.31	0.12	1020	9.41	9598	N/A	N/A	
Classroom W314	75	49	430	1.12	0.09	1005	9.5	9548	520	3.3	
Research W318	76.9	53	432	0.97	0.16	1190	8.5	10115	N/A	N/A	
Student Lounge 340	70.7	58.8	427	1.58	0.08	1002	9.66	9679	N/A	N/A	
Kiva E372	76.8	49.2	430	1.3	0.08	1014	9.5	9633	N/A	N/A	
Classroom E377	75.4	53.7	424	0.96	0.13	947	9.5	8997	520	3.5	
Art E380	76.7	48.7	438	0.77	0.08	1177	9.5	11182	520	2.8	
Chemistry E382	77.4	46.9	428	1.22	0.09	1223	9.5	11619	520	2.7	
Basement											
Parking Garage	69.3	47.2	418	0.24	0.08	29711	11.83	351481	N/A	N/A	
IT Office B11	70.8	50.7	435	0.47	0.06	206	9.41	1938	120	3.7	

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.

A.L.L 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	Cafeteria-A	2110	200	9.5	(4) 20x20x2	8	192	#1, #2, #3	#2 or #3	b
AHU-2	KIVA'S	5025	400	8	(4) 20x25x2	8	364	#1, #2, #3	#2 or #3	b, c
AHU-3	CORRIDORS	9,905	4,000	40.4	N/A	8	N/A	#1, #2, #3	#2 or #3	b, c
AHU-4	T.V.	700	200	28.6	(2) 12x20x2	8	411	#1, #2, #3	#2 or #3	a, b, c
AHU-5	T.V. PRODUCTION	700	200	28.6	(2) 12x24x2	8	175	#1, #2, #3	#2 or #3	a, b, c
AHU-6	LOCKERS	1080	200	18.5	(2) 20x20x2	8	196	#1, #2, #3	#2 or #3	b, c
AHU-7	RESEARCH	1050	200	19	(2) 20x20x2	8	191	#1, #2, #3	#2 or #3	b, c
AHU-8	DISCOURSE	880	250	28.4	N/A	8	N/A	#1, #2, #3	#2 or #3	b, c
AHU-9	MUSIC	1010	200	19.8	(2) 12x24x2	8	253	#1, #2, #3	#2 or #3	b
AHU-10	NURSE	425	50	11.8	N/A	8	N/A	#1, #2, #3	#2 or #3	b
AHU-11	RESEARCH	1300	400	30.8	(2) 20x20x2	8	236	#1, #2, #3	#2 or #3	b, c
AHU-12	KIVA'S	7260	800	11	(12) 16x20x2	8	273	#1, #2, #3	#2 or #3	b, c
AHU-13	CORRIDORS	5745	2300	40	(6) 20x20x2	8	344	#1, #2, #3	#2 or #3	b, c
AHU-14	T.V.	900	100	11.1	(2) 12x24x2	8	225	#1, #2, #3	#2 or #3	b, c
AHU-15	RES./DISC.	2320	200	8.6	(4) 16x20x2	8	263	#1, #2, #3	#2 or #3	b
AHU-16	Cafeteria-B	2110	200	9.5	(4) 20x20x4	8	190	#1, #2, #3	#2 or #3	b, c
AHU-17	T.V.	720	100	13.9	(2) 12x24x2	8	180	#1, #2, #3	#2 or #3	b, c
AHU-18	MUSIC	900	100	11.1	(2) 12x24x2	8	225	#1, #2, #3	#2 or #3	b, c
RTU-1	Gymnasium	9850	2500	25.4	(15) 20x25x2 (5) 16x25x2	8	149	#1, #2	#3	c
RTU-2	Gymnasium	9850	2500	25.4	(15) 20x25x2 (5) 16x25x2	8	149	#1, #2	#3	c
UV's	Classrooms	varies	varies	varies	varies	8	varies	#1, #2	#1, #3	a
Misc FC's	Offices	varies	varies	varies	varies	8	varies	#1	#1, #3	a

Ventilation System Summary Notes:

- a. *For individual classrooms, ECCM #1 – Portable Air Filtration and/or ECCM #3 – Ionization is noted as a possible options to improve air cleaning and changeover during pandemic conditions.*
- b. *Improved filtration up to MERV 13 is subject to testing of respective unit to confirm fan can support the increased resistance.*
- c. *Disable any CO2 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 Claremont 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.

Most of the HVAC systems supporting the Claremont School are 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.

Most of the classroom UV systems as well as many of the air handlers and packaged rooftop units have the ability to increase outdoor air for higher outdoor air ventilation and air exchange rate.

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.

Higher filtration on most of the AHU units may be considered subject to unit fan capabilities. Most, other HVAC systems including the classroom unit ventilators and fan coil units cannot support filtration in excess of MERV 8. All replacement filters for these terminal units should meet MERV 8 requirements.

Prior to implementation of higher filtration levels in excess of MERV 8, existing 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 manufacturer 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 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 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: 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 Claremont Schools case they could be installed in the supply air duct of the respective mixed air handling systems and unit ventilators. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Claremont 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 viruses 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, 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

A.L.L. School (Claremont & Woodland)

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	B	C	D	E	F	G	H	I	J	K	L	M	N						
				AWNING	2.88	AWNING	0.52	AWNING	0.52	AWNING	0.43	AWNING	0.49	AWNING	2.89	X	0.52	Door	3024				
Basement - Parking																							
	Parking Area	parking	29711	1188.44																0.00	1188.44	NO	
	B03 - Machine	mech	71	2.84																0.00	2.84	NO	
	B04 - Storage	storage	646	25.84																0.00	25.84	NO	
	B08 - Plam Room	support	366	14.64																0.00	14.64	NO	
	B08A - Fire Prot	support	122	4.88																0.00	4.88	NO	
	B08B - Elect	support	26	1.04																0.00	1.04	NO	
	B10 - Plan Room	support	377	15.08																0.00	15.08	NO	
	B11 - Maint Office	office	206	8.24						4										1.72	6.52	NO	
	B12 - Supply	support	157	6.28																0.00	6.28	NO	
	B13A - Mens Room	toilet	65	2.6																0.00	2.60	NO	
	B13B - Women's Room	toilet	65	2.6																0.00	2.60	NO	
	B15 - Storage	storage	213	8.52																0.00	8.52	NO	
	B16 - Mechanical	mech	533	21.32																0.00	21.32	NO	
	B17 - Mechanical	mech	534	21.36																0.00	21.36	NO	

Third Floor																
W304A - Sup	support	75	3											0.00	3.00	NO
W304B - Sup	support	75	3											0.00	3.00	NO
W305 - Kiva	meeting	1020	40.8											0.00	40.80	NO
W306	classroom	1203	48.12			7								20.16	27.96	NO
W307	classroom	938	37.52			2			3					7.81	29.71	NO
W308	classroom	938	37.52			2			3					7.81	29.71	NO
W310	classroom	846	33.84			3								8.64	25.20	NO
W311 - Spec Ed	classroom	853	34.12			3								8.64	25.48	NO
W312	classroom	906	36.24			2			3					7.31	28.93	NO
W313	classroom	906	36.24			2			3					7.31	28.93	NO
W314	classroom	1005	40.2			3								8.64	31.56	NO
W315 - Science	classroom	1167	46.68						9					5.64	41.04	NO
W316 - Discourse	support	1128	45.12										2	0.00	45.12	NO
W317 - Teacher's Lounge	support	355	14.2											0.00	14.20	NO
W318 - Reaserch & H.O.T.S. Prog	classroom	1190	47.6											0.00	47.60	NO
W318A - Women	toilet	75	3											0.00	3.00	NO
W319 - Men's	toilet	234	9.36											0.00	9.36	NO
W320 - Girl's	toilet	224	8.96											0.00	8.96	NO
W321 - Boy's	toilet	231	9.24											0.00	9.24	NO
W322 - Sup	support	78	3.12											0.00	3.12	NO
W324 - Cust	support	56	2.24											0.00	2.24	NO
W326 - Teachers	support	355	14.2											0.00	14.20	NO
340 - Student Lounge	support	1002	40.08											0.00	40.08	NO
342 - Waiting	office	219	8.76											0.00	8.76	NO
342A - Conference	conference	158	6.32					3						1.55	4.77	NO
343 - A.P.	office	226	9.04						3					1.55	7.49	NO
343A - Toilet	toilet	61	2.44											0.00	2.44	NO
E372 - Kiva	aud	1014	40.56											0.00	40.56	NO
E375	classroom	839	33.56					3						8.64	24.92	NO
E375A - Sup	support	77	3.08											0.00	3.08	NO
E377	classroom	947	37.88					2		3				7.81	30.07	NO
E378	classroom	942	37.68					2		3				7.81	29.87	NO
E379 - Research	classroom	972	38.88					3						8.64	30.24	NO
E379A - Media	support	0	0											0.00	0.00	NO
E379B - Copy	support	0	0											0.00	0.00	NO
E380 - Art	classroom	1177	47.08											5.64	41.44	NO
E381 - Disc / Language	classroom	732	29.28										2	0.00	29.28	NO
E382 - Chemistry / Enviro	classroom	1223	48.92					6						17.28	31.64	NO
E383	classroom	920	36.8							3				7.31	29.49	NO
E384	classroom	918	36.72							3				7.31	29.41	NO
E385 - Spec Ed	classroom	832	33.28											8.64	24.64	NO
E386 - Teacher	support	354	14.16											0.00	14.16	NO
E386A - Men's	toilet	75	3											0.00	3.00	NO
E387 - Women's	toilet	219	8.76											0.00	8.76	NO
E388 - Girl's	toilet	216	8.64											0.00	8.64	NO
E389 - Boy's	toilet	232	9.28											0.00	9.28	NO
E390 - Cust	support	55	2.2											0.00	2.20	NO
E393 - TV Staging	classroom	618	24.72											0.00	24.72	NO
E394 - TV Production	classroom	507	20.28											0.00	20.28	NO
E395 - Edn	support	78	3.12											0.00	3.12	NO
E395A - Sup	support	55	2.2											0.00	2.20	NO
E396 - Teacher	support	354	14.16											0.00	14.16	NO

Window Type	Width	Hieght	Projection	Venting
A - Awning	40	19.25	7	2.88
B - Awning	18	19.25	2	0.52
C - Awning	18	19.25	2	0.52
D - Awning	16.5	14.5	2	0.43
E - Awning	16	19.5	2	0.49
H - Awning	40.25	19.25	7	2.89
X - Awning	16.25	21.25	2	0.52
Door	36	84	1	3024.00

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)