Worcester Public Schools

Ventilation Assessment
&
COVID-19
Mitigation Strategies

for

Forest Grove Middle 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:

Forest Grove Middle School:
Forest Grove Middle School is located in the Dohrety Quadrant of the Worcester at 495 Grove Street. The main portion of the school was built in 1960, houses grades 7-8, has 69 classrooms and the building is 198,713 square feet. The widows are orignal to the school and its additions.

C. Table of Contents:

1) Mechanical Ventilation Report

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I. EXECUTIVE SUMMARY

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

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

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

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

COVID-19 Control Measures:

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

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

<u>CCM #1 – Pre & Post Purge Ventilation</u> – 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 Forest Grove Middle 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.

In review of existing HVAC drawings, it appears that many of the classrooms appear to meet or exceed the 3 ACH requirement. The common area systems gymnasium, auditorium and cafeteria HVAC systems 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. Many of the classrooms HVAC systems throughout the building cannot support additional outside air as the outdoor air systems are at their design capacity.

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

The cafeteria, auditorium, library and office air handling systems may support improved filtration up to a maximum of MERV 13 pending testing and verification as their age and fan capabilities may limit filtration to MERV 11 or 8. Most other classroom and office systems in the building will not support increased filtration above MERV 8 either due to physical equipment limitations (i.e., fan coils & FVAV’s limited to 1” filters) or due to 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.

Systems retrofitted with MERV 13 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.

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 Forest Grove Middle 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 Forest Grove Middle School appear to 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 Forest Grove Middle School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
General & Science Classrooms	Unit Ventilators	CCM - #1 & #2 (add exhaust for science) ECCM - #1 or #3 (*see note below)
Art Classrooms	Rooftop Air Handler	CCM - #1 #2 (add exhaust) ECCM - #3
Auditorium	Rooftop Air Handler	CCM - #1 & #2 ECCM - #3
Gymnasium	Rooftop Air Handlers	CCM - #1 & #2 ECCM - #3
Admin. Office	Rooftop Air Handlers VAV	CCM - #1 & #2 (add OA flow control) 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 / 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.

There are no existing HVAC design drawings or equipment schedules available for review of original design intent. As such, we cannot comment on the existing ventilation levels in every instance. Our review is based on review of sheet metal as-built drawings, control drawings as well as our site inspection. If design drawings cannot be found, we suggest field airflow testing as well as further review with the control vendor to establish ventilation levels.

General Classrooms:

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 associate 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. 400 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 from rooms is primarily thru gravity wall or roof hoods. This type of exhaust/relief would generally place the rooms under a slight positive pressure.

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. 400 CFM+/- provide more than the code required outdoor air to the rooms.

There are select other areas which are heated and cooled with 2-pipe fan heating/cooling coil units. These units are also fed with hot water and chilled water from the central boiler and 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 fan coil units bring in outdoor air thru exterior wall louvers or intake hoods and recirculate heated, cooled, or neutral air within the room they serve. As is the case with the unit ventilators, these units relieve air thru gravity wall or roof hoods.

A DDC space thermostat controls the operation of the hydronic valve in the units as well as the respective outdoor air dampers and the fan with occupied and unoccupied schedules. The units should be programmed for continuous fan mode during occupied periods with outdoor air dampers open to minimum position and the discharge air temperature varying based on deviation from space temperature setpoint. During unoccupied periods, the fans cycle off and only cycle on with the associated hot water valve opening when there is a need for heating.

Art & Science Rooms:

The science rooms are supported by the same types of unit ventilators and outdoor air rates as typical classrooms. The art rooms are served by a rooftop air handler however the scheduled outdoor air does not appear to be able to comply with the code required exhaust for this space. Both science and art room rely in gravity relief louvers or roof hood to vent air from the space whereas exhaust should be provided via positive mechanical means.

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. It appears the buildings ventilation levels for both the science rooms and the art room are not compliant with current ventilation code. If the science rooms are more of a physics type room where not chemicals or gas is used consideration may be allowed to not require the elevated air exchange rates.

Offices:

The administration office areas are supported by a packaged rooftop HVAC unit. The unit are fitted with a mixing box, filter section, hot water coil section, DX cooling section and supply fan. The system serves VAV terminals.

As these are mixed air systems, the amount of outdoor air delivered to each space varies based on the amount of primary air being introduced through the respective VAV terminal. According to the design drawings the percentage of outdoor air from the RTU serving these areas is 43% of the design supply air. This amount of outside air is relatively high and should provide adequate ventilation to the administration areas with moderate occupancy.

However, if the primary air reduces which it does for a typical VAV terminal, the percentage of outdoor air would drop thereby potentially under ventilating the space. For example, if a VAV terminals primary air dropped to 30% of design, the amount of outdoor air to this room would also drop potentially under ventilating the room.

Current mechanical code would require VAV systems such as this to have the ability to maintain the outdoor air volume constant across the unit's variable supply airflow operation. For example, if the unit provided 40% outside air at full airflow, if the units total airflow dropped to 50%, the outdoor airflow quantity should remain constant thereby making the outdoor air percentage 80%. This would help maintain proper outdoor airflow to the various spaces as there VAV terminals vary. Based on the current control drawings, the existing units do not operate in this fashion and do not monitor the amount of outdoor air the units are introducing.

In addition, these types of multi-zone systems generally require a higher percentage of outdoor air to achieve compliance with current code and ASHRAE 62.1-Ventilation for Acceptable Indoor Air Quality standards. These standards factor in the individual ventilation needs of various spaces in a multi-zone system as well as the respective VAV terminals minimum and maximum ranges.

Although the unit is older, the filters may be able to be increased to a MERV level as high as MERV 13 pending testing and confirmation of fan capabilities. If increased to MERV 13, more frequent replacement of the filters shall be required to avoid reduction in airflow as filters load.

<u>Auditorium, Media Center, Gymnasium, Cafeteria:</u>

The gymnasium, auditorium and media center are heated, cooled, and ventilated through the use of rooftop HVAC. The units are fitted with a mixing box, filter section, hot/chilled water coil, DX cooling section (auditorium and admin. only) supply and return fans. The filters on HV units are 2" thick pleated filters with an estimated MERV rating of 8. The filters on the HVAC RTU units are both 2" and 4".

Although the units are older, the filters for these units, may be able to be increased to a MERV level as high as MERV 13 pending testing and confirmation of fan capabilities. If increased to MERV 13, more frequent replacement of the filters shall be required to avoid reduction in airflow as filters load.

Current code would require the following outdoor air for the respective spaces:

- Gymnasium: 0.3 CFM per SF play area (+ undetermined spectator area)
- Cafeteria: 7.5 CFM per person of outside air plus 0.18 CFM per SF
- Library: 5 CFM per person of outside air plus 0.12 CFM per SF

The cafeteria system consists of unit ventilators similar in configuration to those in the classrooms.

The existing design drawings reflect outdoor air volumes that should comply with current ventilation code with moderate occupancy levels for these spaces. The control drawings for both the gymnasium and auditorium systems reflect the utilization of CO_2 sensors with controls for demand ventilation reset off space CO_2. These reset controls should be disabled to ensure outdoor air volumes are kept at design levels during the pandemic condition. The gymnasium also reflects occupancy sensor control which would need to be overridden to allow for pre- and post-purge ventilation.

Controls:

Most of the major HVAC systems supporting the school are controlled by a building energy management system (EMS) by ABS. It appears ABS has taken over an existing control system and as such there may be some limitation to modifying controls on existing systems to achieve some measures. Further review with ABS is recommended prior to implementing control changes.

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.

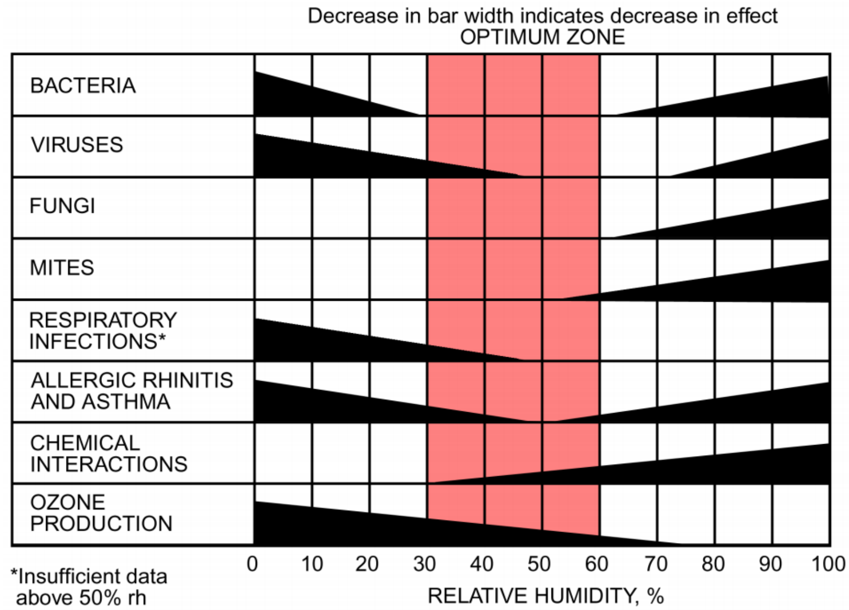

Fig. 1 Optimum Humidity Range for Human Comfort and Health
(Adapted from Sterling et al. 1985)

The Forest Grove Middle 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., 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 or renovated structures, such as Forest Grove Middle 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". Many of the general classrooms in the Forest Grove Middle School have a design outdoor air exchange rate of 3 or greater which is above the bare minimum criteria. 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.

Forest Grove 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											
Classroom 102	69.8	48.1	483	0.66	0.09	891	8.41	7493	400	3.2	
Classroom 107	69.2	46.7	488	0.83	0.1	885	8.41	7443	400	3.2	
Classroom 108	69.7	40.5	507	0.8	0.08	675	8.41	5677	N/A	N/A	
Classroom 114	70.5	41.1	506	0.63	0.07	828	8.41	6963	N/A	N/A	
Classroom 121	69.7	42.7	487	0.3	0	871	8.41	7325	400	3.3	
Classroom 126	69.8	45.5	482	0.23	0.08	775	8.41	6518	400	3.7	
Classroom 116	70.7	38.2	515	0.7	0.1	1247	8.83	11011	375	2	
Classoom 131	70.2	44.2	516	0.56	0.12	734	8.41	6173	N/A	N/A	
Library Media	70.2	43.9	503	0.66	0.07	5028	10	50280	750	0.9	
Health Suite	70.5	45.8	488	0.53	0.08	917	8	7336	81	0.7	
Main Office	71	38.1	534	0.54	0.09	552	8.41	4642	188	2.4	
Gym	68.9	50.9	457	0.37	0.07	7284	28.12	204826	4400	1.3	
Exercise Room	68.8	45.2	482	0.26	0.06	891	8.66	7716	N/A	N/A	
Boys Locker Room	68.1	44.5	412	0.32	0.06	566	8.5	4811	N/A	N/A	
Cafeteria	71.4	44.2	510	0.4	0.04	5083	11.41	57997	5250	5.4	
Auditorium	70.5	46.7	453	0.35	0.07	4868	22.75	110747	5250	2.8	
Music Rm 145	70.1	43.2	446	0.21	0.07	1378	10.16	14000	N/A	N/A	
Classroom 141	69.3	47.2	499	0.68	0.14	718	8.41	6038	400	4	
Computer Rm 154	69.5	47.1	422	0.43	0.08	945	8.75	8269	400	2.9	
Classroom 155	68.9	42.8	478	0.43	0.07	1227	8.66	10626	500	2.8	
2nd Floor											
Classeoom 207	70.7	43	476	0.37	0.06	885	8.41	7443	400	3.2	
Classroom 208	70.5	42.2	501	0.32	0.13	885	8.41	7443	400	3.2	

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.

Forest Grove Middle 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
RTU-1	Gymnasium	6500	2200	34	(10) 16x25x2 (10) 16x20x2	8	N/A	#1, #2	#3	b
RTU-2	Gymnasium	6,500	2,200	34	(10) 16x25x2 (10) 16x20x2	8	N/A	#1, #2	#3	b
RTU-3	Auditorium	11,000	5,250	48	(10) 16x25x2 (10) 20x25x2	8	N/A	#1, #2	#3	b
RTU-4	Admin Office	5000	2140	43	N/A	8	N/A	#1, #2	#1, #3	a, b, d
RTU-5	Corridor Classrooms	7000	3400	49	(4) 16x25x2 (2) 20x25x2	8	N/A	#1, #2	#3	
AC-1	Art Room	9000	1500	17	N/A	8	N/A	#1, #2	#3	c
AC-2/RTU-6	Media Center	8000	750	10	(6) 20x25x2	8	384	#1, #2	#3	b
Misc FC's	Misc.	varies	varies	varies	varies	8	varies	#1	#1, #3	a
Misc. UV's	Classrooms	varies	varies	varies	varies	8	varies	#1, #2	#1, #3	a , c

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. *Disable any CO2 demand ventilation reset or occupancy sensor-based system shutdown (during scheduled occupied periods) during pandemic conditions.*

c. *Provide mechanical exhaust for art and science rooms and increase OA as required (mechanical modifications required).*

d. *To improve the ventilation effectiveness and outdoor airflow control of the admin. Office VAV system we would recommend airflow stations be added to the outdoor airflow and exhaust airflow of the RTU unit along with associated control improvements.*

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 Forest Grove Middle 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 Forest Grove Middle School are 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.

The UV's as well as the RTU and AC units have the ability to increase outdoor air for increase outdoor air ventilation and air change rate.

CCM #3 – Improved Filtration

Improve filtration of 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.

Filtration of MERV 13 may be possible on the RTU and AC units subject to system testing although their age does not make them good candidates. Most, 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 manufucturer. 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 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: 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 Forest Grove Middle Schools case they could be installed in the supply air duct of the respective mixed air handling systems as well as in unit ventilators and fan coil units. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Forest Grove Middle 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

Forest Grove Middle School

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	A AWNING	4.72	B AWNING	4.06	C AWNING	3.94	D AWNING	3.11	Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
First Floor															
Room 101	classroom	891	35.64		6							28.33	7.31	NO	
Room 102	classroom	891	35.64									0.00	35.64	NO	
Boy's Room	toilet	156	6.24				1					4.06	2.18	NO	
Girl's Room	toilet	202	8.08				1					4.06	4.02	NO	
Room 103	classroom	885	35.4		6							28.33	7.07	NO	
Room 104	classroom	771	30.84		4							18.89	11.95	NO	
Faculty A	office	170	6.8									0.00	6.80	NO	
Faculty B	office	173	6.92									0.00	6.92	NO	
Room 105	classroom	883	35.32		6							28.33	6.99	NO	
Room 105 - Office	office	186	7.44									0.00	7.44	NO	
Women's Room	toilet	128	5.12									0.00	5.12	NO	
Comm	office	54	2.16									0.00	2.16	NO	
Room 106	classroom	375	15									0.00	15.00	NO	
Room 107	classroom	885	35.4		6							28.33	7.07	NO	
Room	office	416	16.64									0.00	16.64	NO	
Office - A	office	102	4.08									0.00	4.08	NO	
Office - B	office	117	4.68									0.00	4.68	NO	
Room 108	classroom	675	27									0.00	27.00	NO	
Room 109	classroom	885	35.4		6							28.33	7.07	NO	
Room 110	classroom	700	28									0.00	28.00	NO	
Room 111	classroom	785	31.4		4		2					27.00	4.40	NO	
Room 112	classroom	628	25.12									0.00	25.12	NO	
Room 113	classroom	785	31.4		4		2					27.00	4.40	NO	
Storage	storage	456	18.24									0.00	18.24	NO	
Room 114	classroom	828	33.12									0.00	33.12	NO	
Room 115	classroom	883	35.32		4		2					27.00	8.32	NO	
Room 116	classroom	1247	49.88									0.00	49.88	NO	
Room 117	classroom	885	35.4		6							28.33	7.07	NO	
Room 118	classroom	1247	49.88									0.00	49.88	NO	
Boy's Room	toilet	200	8				1					4.06	3.94	NO	
Girl's Room	toilet	203	8.12				1					4.06	4.06	NO	
Room 119	classroom	402	16.08		2							9.44	6.64	NO	
Room 120	classroom	6099	243.96									0.00	243.96	NO	
Storage	storage	362	14.48									0.00	14.48	NO	
Room 121	classroom	871	34.84									0.00	34.84	NO	
Room 121 - Office	office	136	5.44									0.00	5.44	NO	
Room 122	office	217	8.68									0.00	8.68	NO	
Men's Room	toilet	128	5.12									0.00	5.12	NO	
Room 123	classroom	873	34.92									0.00	34.92	NO	
Room 124	classroom	775	31				6					24.33	6.67	NO	
Room 125	classroom	775	31									0.00	31.00	NO	
Room 126	classroom	775	31									0.00	31.00	NO	
Room 128	classroom	775	31									0.00	31.00	NO	
Main Office	office	552	22.08									0.00	22.08	NO	
Work office	office	185	7.4									0.00	7.40	NO	
A.P. Office - A	office	164	6.56									0.00	6.56	NO	
A.P. Office - B	office	164	6.56									0.00	6.56	NO	
A.P. Office - C	office	154	6.16									0.00	6.16	NO	
Men's Room	toilet	60	2.4									0.00	2.40	NO	
Women's Room	toilet	60	2.4									0.00	2.40	NO	
Principal	office	264	10.56									0.00	10.56	NO	
Kitchen	café	146	5.84									0.00	5.84	NO	
Conference	conference	626	25.04									0.00	25.04	NO	
Health Suite	classroom	275	11									0.00	11.00	NO	
Rest.	support	396	15.84									0.00	15.84	NO	
Office - A	office	123	4.92									0.00	4.92	NO	
Exam	office	123	4.92									0.00	4.92	NO	
Office - B	office	123	4.92									0.00	4.92	NO	
Office - C	office	123	4.92									0.00	4.92	NO	
Office - D	office	123	4.92									0.00	4.92	NO	
AHU	support	123	4.92									0.00	4.92	NO	
Guidance Suite	office	530	21.2									0.00	21.20	NO	
Library / Media	library	5028	201.12									0.00	201.12	NO	
Storage	storage	389	15.56									0.00	15.56	NO	
Head End	support	294	11.76									0.00	11.76	NO	
Work	office	289	11.56									0.00	11.56	NO	
Office	office	116	4.64									0.00	4.64	NO	
Faculty Dinning	café	784	31.36									0.00	31.36	NO	
Dark Room	classroom	267	10.68									0.00	10.68	NO	
Room 131 A	classroom	734	29.36									0.00	29.36	NO	
Room 131 B	classroom	782	31.28									0.00	31.28	NO	
Room 133	classroom	1220	48.8									0.00	48.80	NO	
Room 135	classroom	1220	48.8									0.00	48.80	NO	
Room 137	classroom	720	28.8									0.00	28.80	NO	
Storage	storage	230	9.2									0.00	9.20	NO	
Office - A	office	126	5.04									0.00	5.04	NO	
Office - B	office	131	5.24									0.00	5.24	NO	
Spec Ed	classroom	197	7.88									0.00	7.88	NO	
Office - C	office	123	4.92									0.00	4.92	NO	
Office - D	office	126	5.04									0.00	5.04	NO	
Room 138	classroom	713	28.52		5							23.61	4.91	NO	
Boy's Locker Room	gym	1337	53.48									0.00	53.48	NO	
Boy's Locker Room Storage	storage	213	8.52									0.00	8.52	NO	
Storage - A	storage	299	11.96									0.00	11.96	NO	
Storage - B	storage	299	11.96									0.00	11.96	NO	
Girl's Locker Room	gym	1335	53.4		11							51.94	1.46	NO	
Girl's Locker Room Storage	storage	202	8.08									0.00	8.08	NO	
Coaches Office & St	office	242	9.68									0.00	9.68	NO	
Aerobics	gym	835	33.4									0.00	33.40	NO	
Men's Room	toilet	134	5.36									0.00	5.36	NO	
Women's Room	toilet	133	5.32									0.00	5.32	NO	
Gym Lobby	gym	608	24.32									0.00	24.32	NO	
Exercise	gym	891	35.64									0.00	35.64	NO	
Gym	gym	7284	291.36									0.00	291.36	NO	
Cafeteria	café	5083	203.32		10							47.22	156.10	NO	
Kitchen	café	2080	83.2									0.00	83.20	NO	
Dishes	café	220	8.8									0.00	8.80	NO	
Storage - A	storage	340	13.6									0.00	13.60	NO	
Storage - B	storage	83	3.32									0.00	3.32	NO	
Storage - C	storage	54	2.16									0.00	2.16	NO	
Office	office	80	3.2									0.00	3.20	NO	
Auditorium	aud	4868	194.72									0.00	194.72	NO	
Stage	aud	1909	76.36									0.00	76.36	NO	
Room 141	classroom	718	28.72		3							14.17	14.55	NO	
Room 143	classroom	705	28.2		3							14.17	14.03	NO	
Room 145	practice room	1378	55.12		3							14.17	40.95	NO	
Girl's Room	toilet	137	5.48									0.00	5.48	NO	
Boy's Room	toilet	137	5.48									0.00	5.48	NO	
Rec	support	147	5.88									0.00	5.88	NO	
Storage	storage	147	5.88									0.00	5.88	NO	
Storage	storage	367	14.68									0.00	14.68	NO	
Storage	storage	132	5.28									0.00	5.28	NO	
Men's Room - A	toilet	112	4.48									0.00	4.48	NO	
Men's Room - B	toilet	107	4.28									0.00	4.28	NO	
Girl's Room	toilet	157	6.28									0.00	6.28	NO	
Boy's Room	toilet	127	5.08									0.00	5.08	NO	
Room 151	classroom	945	37.8						4			15.78	22.02	NO	
Room 152	classroom	945	37.8		4							18.89	18.91	NO	
Room 153	classroom	939	37.56						4		2	22.00	15.56	NO	
Room 154	classroom	945	37.8		4							18.89	18.91	NO	
Room 155	classroom	1227	49.08		5							23.61	25.47	NO	
Room 155 - Storage	storage	60	2.4									0.00	2.40	NO	
Room 156	classroom	1484	59.36		5							23.61	35.75	NO	
Room 156 - Finish	support	106	4.24									0.00	4.24	NO	
Room 156 - Dust	support	107	4.28									0.00	4.28	NO	

Second Floor

Room 201	classroom	901	36.04	6				28.33	7.71	NO
Room 202	classroom	879	35.16	6				28.33	6.83	NO
Boy's Room	toilet	158	6.32		1			4.06	2.26	NO
Girl's Room	toilet	212	8.48		1			4.06	4.42	NO
Room 203	classroom	875	35	6				28.33	6.67	NO
Room 204	classroom	869	34.76	6				28.33	6.43	NO
Storage Room - A	storage	210	8.4					0.00	8.40	NO
Storage Room - B	storage	213	8.52					0.00	8.52	NO
Room 205	classroom	875	35	6				28.33	6.67	NO
Room 205 - Office	office	135	5.4					0.00	5.40	NO
Storage Room	storage	142	5.68					0.00	5.68	NO
Room 206	classroom	875	35	6				28.33	6.67	NO
Room 207	classroom	875	35	6				28.33	6.67	NO
Room 208	classroom	872	34.88	6				28.33	6.55	NO
Room 209	classroom	875	35	6				28.33	6.67	NO
Room 210	classroom	774	30.96	4	2			27.00	3.96	NO
Room 211	classroom	813	32.52	4	2			27.00	5.52	NO
Room 212	classroom	776	31.04	4	2			27.00	4.04	NO
Room 213	classroom	775	31	4	2			27.00	4.00	NO
Room 214	classroom	776	31.04	4	2			27.00	4.04	NO
Room 215	classroom	875	35	4	2			27.00	8.00	NO
Room 216	classroom	776	31.04	4	2			27.00	4.04	NO
Room 217	classroom	875	35	6				28.33	6.67	NO
Room 217 - Storage	storage	83	3.32					0.00	3.32	NO
Storage	storage	101	4.04					0.00	4.04	NO
Boy's Room	toilet	195	7.8		1			4.06	3.74	NO
Girl's Room	toilet	203	8.12		1			4.06	4.06	NO
Room 218	classroom	776	31.04	4	2			27.00	4.04	NO
Room 219	classroom	405	16.2	2				9.44	6.76	NO
Room 220	classroom	783	31.32	4	2			27.00	4.32	NO
Storage Room - A	storage	126	5.04					0.00	5.04	NO
Storage Room - B	storage	125	5					0.00	5.00	NO
Room 221	classroom	848	33.92	6				28.33	5.59	NO
Room 221 - Office	office	136	5.44					0.00	5.44	NO
Storage	storage	128	5.12					0.00	5.12	NO
Room 222	classroom	411	16.44	2				9.44	7.00	NO
Room 223	classroom	873	34.92	6				28.33	6.59	NO
Room 224	classroom	779	31.16	4	2			27.00	4.16	NO
Room 225	classroom	769	30.76	4	2			27.00	3.76	NO
Room 226	classroom	776	31.04	4	2			27.00	4.04	NO
Room 228	classroom	769	30.76	4	2			27.00	3.76	NO

Window Type	Width	Hieght	Projection	Venting
A - Awning	43	42	8	4.72
B - Awning	31	42	8	4.06
C - Awning	42	29	8	3.94
D - Awning	34	22	8	3.11

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)