Worcester Public Schools

Ventilation Assessment
&
COVID-19
Mitigation Strategies

for

Burncoat High School
Worcester, MA

January 31, 2021

Prepared by:

Nault Architects Inc
71 Hope Ave
Worcester, MA 10603

Seaman Engineering Corporation
22 West St, Unit C
Milbury, MA 01527

&

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:

Doherty High School:
Doherty High School is located in the Dohrety Quadrant of the Worcester at 299 Highland Street. The School was built in 1966, houses grades 9-12, has 64 classrooms and the building is 144,388 square feet. The widows are orignal to the school and many are not fully functional.

C. Table of Contents:

1) Mechanical Ventilation Report 19

2) Natural Ventilation Summary.. 5

1) Mechanical Ventilation Report

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY………………………………………………………………. 2

II. HVAC VENTILATION ASSESSMENT..….. 5
A. General……………………………………………………………………………… 5
B. Evaluation…………...… 7
C. IAQ & Ventilation Summary...… 11

III. COVID-19 HVAC MITIGATION MEASURES……………... 16
A. HVAC COVID-19 Control Measures………………………………………………. 16
B. Enhanced HVAC COVID-19 Control Measures ……………………………………… 18

I. EXECUTIVE SUMMARY

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

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

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

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

COVID-19 Control Measures:

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

As of the writing of this report, the City of Worcester Public Schools (WPS) has already begun implementation of several of the measures noted below. For enhanced measures, WPS has begun to incorporate Bipolar Ionization (see ECCM-#3) extensively throughout the Burncoat High 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 Burncoat High 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 HVAC systems supporting the Burncoat High School are either already meeting the 3 ACH requirement or are capable of increasing outdoor air subject to outdoor ambient conditions and equipment limitations.

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

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

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

ECCM #1: Portable Room Purifiers - Portable room air purifiers could be used in select areas 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 improved system ventilation.

ECCM #2: UV-C Light Sterilization - UV-C lights could be considered for insertion in equipment and ductwork to help neutralize viruses 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 Burncoat High 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 Burncoat High 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 Burncoat High School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
General Classrooms	Mixed Air Systems Hot & Cold Deck	CCM - #1, #2 & #3 ECCM - #1 or #3 (*see note below)
Science & Chemistry Classrooms	Mixed Air Systems Hot & Cold Deck	CCM - #1, #2 & #3 (+ ERV or dedicated exhaust for science) ECCM - #1 or #3 (*see note below)
Art Classrooms	Mixed Air Systems Hot & Cold Deck	CCM - #1, #2 & #3 (+ ERV or dedicated exhaust) ECCM - #3
Gymnasium	Mixed Air Systems HV Air Handler	CCM - #1 & #2 ECCM - #3
Admin. & Guidance Office	Mixed Air Systems Hot & Cold Deck	CCM - #1, #2 & #3 ECCM - #1 or #3 (*see note below)
Trade Shops	Mixed Air Systems Hot & Cold Deck	CCM - #1, #2 & #3 ECCM - #3

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

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

II. HVAC VENTILATION ASSESSMENT

A. GENERAL

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

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

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

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

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

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

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

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

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

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

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

B. EVALUATION

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

General Classrooms:

A majority of the classrooms in the building are heated, ventilated and cooled via multiple heating and ventilation (HV) air handling units located in mechanical rooms that are generally below the level of the floor being served. These units are of the hot deck cold deck type with either zone dampers at the unit or downstream in dual port mixing terminals. These units consist of a mixing chamber, filter section, hot water coil, supply and return fans. Most of the units and mixing terminals were converted to variable air volume (VAV) in a subsequent renovation/upgrade. Hot water is fed to all these units from the building's central boiler plant. The larger systems are fitted with 4" thick air filters and smaller systems with 2" thick filters all with an estimated efficiency of MERV 8.

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

Each of the classroom air handlers deliver conditioned air to the classroom and associated spaces via a ducted supply air system and a partially ducted plenum return air system. The supply air to a majority of the classrooms run through a dual duct VAV terminal fitted with damper operators for control of primary air and temperature of air delivered to the space they serve. A DDC space thermostat controls the operation of the VAV damper.

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 each of the central systems is approximately 35% of the design supply air.

For a standard classroom, current code would require 10 CFM per person of outside air plus 0.12 CFM per SF. The zone air distribution effectiveness for most of the classrooms is 1.0 with some being 0.8 with the lower factor due to the presence of ceiling supply and return terminals coupled with air that may be warmer than 15°F above space in certain areas such as those spaces with greater thermal heat loss. As such, an average classroom of 800 SF with 26 occupants (25 students + 1 teacher) would require 445 CFM inclusive of the 0.8 correction or 356 CFM with the 1.0 factor.

As noted previously most of the classrooms are supported from a VAV system. These terminals deliver a maximum total and primary airflow of approximately 1,200 CFM +/- (varies by room). Based on the supporting RTU systems having 33% or more outside air, per design, this would yield a maximum of 400 CFM of outside air to a room. This amount is close to meeting current code required outdoor air of 356 CFM to 445 CFM depending on space air distribution effectiveness. 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.

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. The old control and VAV retrofit plans reflect an attempt to address this by increasing OA as the supply air drops on at least three (3) of the main systems (SF-B-1, SF-C-1 and SF-D-1) however, there is no OA flow station reflected to ensure ventilation is being maintained. An OA flow station should be added to ensure proper OA ventilation is maintained.

Current EMS control drawings reflect a demand ventilation reset of OA based on return air CO2. This is an effective approach if a CO2 sensor was in each room or space served however, being in a common return is not be a good indication of proper outdoor air for a multi-zone system. This is due to the fact that the common return does not reflect the zone with maximum occupant demand therefore lower occupant zones can dilute the CO2 reading causing the controls to reduce outside thereby impacting all zones including the ones that may require more outside air.

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.

During pandemic conditions we recommend any demand ventilation reset schemes be disabled to insure increase outdoor air to the spaces. In addition, increase of outdoor air and VAV minimum settings would aide in providing additional OA ventilation.

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

The science rooms and the art room are supported by the same central HV units as the normal classrooms. The current science/chemistry rooms are approx. 1,050 SF in size and are each supplied with 1,400+ CFM of supply air from a dual duct VAV terminal.

Per the current code, science rooms and art rooms require higher ventilation levels than general use classrooms. Art rooms require 0.7 CFM/SF of exhaust and Science rooms require 1.0 CFM per SF of exhaust. It appears the ventilation levels to these areas comply with outdoor air requirements but for the science rooms not the exhaust air requirements nor the prohibition on recirculation air as the lab air mixes with other spaces through the central HV unit.

As the science rooms mix with the common HV system more aggressive modifications may be required to address the current deficiency which may include the addition of room exhaust which can pull room from the space to prevent recirculation with the balance common from common plenum air or with the addition of a dedicated energy recovery ventilation unit.

Gymnasium & Cafeteria:

The gymnasium and cafeteria spaces are supplied with air from multiple single zone style HV air handlers located in a mechanical space or, for the gymnasium suspended within the space it serves. The air handlers are mixed air units which introduces a percentage of outside air into the recirculating air stream. Each unit has mixing dampers, angle filter box, hot water heating coil and a fan section. Relief air from the space is accomplished via two (2) locker room HV units which take air from the gymnasium as well as outdoor air to feed the locker room make-up air needs. Although, we were not able to access the units during our inspection the air handling units appear to have 2" pleated filters with an estimated MERV rating of 8.

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

The gymnasium ventilation needs are based on a percentage of play area and spectator area. Play area requires an outdoor air volume of 0.3 CFM per SF whereas the spectator area requires 7.5 CFM per person plus 0.06 CFM per SF. The zone air distribution effectiveness is 1.0 based on ceiling supply and floor returns. With actual spectator area unknown, presuming the entire gym is play area, would yield a required outdoor air rate of 2,680 CFM.

Per the control drawings each unit's minimum outside air is 25% of the design supply volume which would equate to 4,500 CFM for the gymnasium space. Although the spectator occupancy and area must be verified, it appears the gymnasium space would be capable of accommodate quite a few occupants at these rates. The control drawings do reflect both occupancy sensors and CO_2 sensors which can accomplish demand ventilation reset control. These features should be disabled during pandemic conditions to allow for increased outdoor air.

Offices:

The offices are supported by a dedicated central HV air handling unit (HV-A-1) which is similar in configuration to those which support the classrooms however control of the VFD's on the fans is not clear based on existing control drawings. This multizone unit has zone dampers at the air handler as opposed to downstream in VAV terminals.

An older type of hot deck cold deck unit will maintain supply air volume by adjusting the airflow to the zones via the hot deck and cold deck damper system. This tends to be an inefficient mode of operation as the system is constantly heating or cooling the zones however, by doing so it maintains near constant ventilation. As the current systems has no cooling coil, the inefficiency is not as much of an issue as the cold deck tends to be neutral mixed air. According to the control drawings the outdoor on this system is 20 % or 1,200 CFM of the 6,250 CFM unit however, original design drawings showed a much higher OA at almost 65%.

The outdoor air requirements for office spaces tend to be lower than that of classrooms as densities are far lower. We suggest confirmation of the OA control as well as the speed control on the fans be confirmed. It is apparent based on the original drawings that the system has the ability to support higher outdoor air. During these pandemic conditions, we recommend OA levels be increased and any CO_2 demand ventilation reset be disabled to insure higher OA levels.

<u>Trade Shops</u>:

The trade shops are supported by the same type of central HV unit (HV-F-1/D-1) as the administration office area. The current rooms vary in size and use as well as the amount of ventilation air.

Per the current code, the trade shops require higher ventilation levels than general use classrooms. As these areas mix with the common HV system more aggressive modifications may be required to address the current deficiency which may include the addition of room exhaust which can pull room from the space to prevent recirculation with the balance common from common plenum air or with the addition of a dedicated energy recovery ventilation unit.

For example, the automotive shop requires 0.75 CFM per SF of exhaust and associated make-up air. Although there is some local exhaust in the space it appears the current system does not support the exhaust air requirements nor the prohibition on recirculation air as the shop air mixes with other spaces through the central HV unit.

<u>Controls</u>:

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

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.

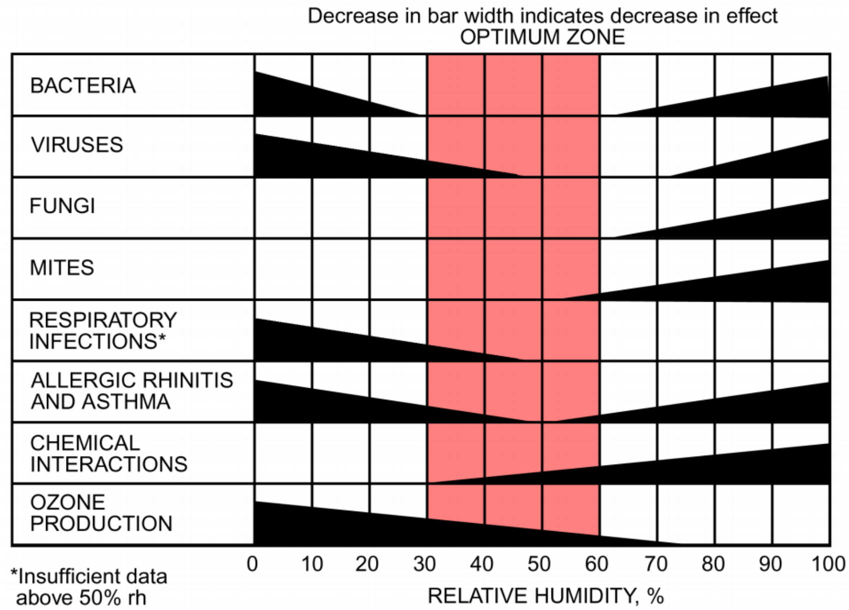

Fig. 1 Optimum Humidity Range for Human Comfort and Health
(Adapted from Sterling et al. 1985)

The Burncoat High School HVAC systems have no active humidity control.

Space dehumidification is limited only to those areas which have air conditioning cooling. However, this dehumidification is not actively controlled by a humidity setpoint. Moisture removal only occurs when these systems are operating in the cooling mode. As such, space humidity may climb above 60% during periods when low thermal loads require less cooling (i.e., a cool damp day) or swing above and below 60% as the systems cycle based on space temperature.

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

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

The document entitled "5-Step Guide to Checking Ventilation Rates in Classrooms" from the Harvard T.H. Chan School of Public Health recommends a target outdoor air exchange rate during these pandemic conditions. The document identifies 5 air changes per hour (ACH) and above as "excellent" down to a 3 ACH being considered "bare minimum". Many of the general classrooms in the Burncoat High School have a design outdoor air exchange rate of approx. 3 or above, meeting the bare minimum criteria so long as the system outdoor air can be controlled as noted herein. 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.

			Burncoat High School IAQ Sampling Summary								
									Original	**Original**	
Space Tested	**Temp.**	**Humidity**	**CO2**	**TVOC**	**HCHO**	**Room Area**	**Room Ht.**	**Volume**	**Design OA**	**OA Air**	**Notes**
	°F	**% RH**	**ppm**	**ppm**	**ppm**	**SqFt**	**Ft**	**Cubic Feet**	**CFM**	**ACH**	
O.A. Cond. -/-/20 Time:											
A Wing											
Main Office	66.7	39.8	429	0.19	0	724	9.08	6574	240	2.2	
Reading	65.8	33.4	419	0.08	0	788	9.25	7289	240	2	
B Wing											
Math	67.2	39.2	424	0.26	0	820	9.25	7585	396	3.1	
Science	67.6	37.6	420	0.18	0	1057	9.08	9598	495	3.1	
Cafeteria	71.3	30.7	425	0.34	0	2171	9.58	20798	4620	13.3	
Kitchen	70.7	33.7	429	0.27	0	2452	10.05	24643	4600	11.2	
C Wing											
Art	68.2	37.9	451	0.18	0	1075	10.16	10922	4620	25.4	
Physics	65	39.1	426	0.11	0	1032	9.08	9371	1360	8.7	
Computer Lab 4	69.1	39.1	433	0.34	0	822	9.08	7464	428	3.4	
Library	65.2	39	422	0.46	0	2019	9.08	18333	544	1.8	
D Wing											
Cafeteria D-7	70.3	35	414	0.03		2491	9.58	23864	2800	7	
D-1	71.3	33.5	436	0.55	0	874	9.08	7936	602	4.6	
D-6	70.9	36.3	491	0.36	0	615	9.08	5584	740	7.9	
Lower D-Wing											
Science	73.3	35	418	0.82	0	1048	9.16	9600	602	3.8	
E Wing											
Home Economics E-6	67	37.4	414	0.2	0	1194	9.05	10806	510	2.8	
Horticulture E-1	66.4	38.4	419	0.17	0	1114	9.08	10115	578	3.4	
F Wing											
Tech Drawing F-4	64.5	39	417	0.4	0	1062	10.6	11257	375	2	
Graphic Arts f-6	64.8	39	414	0.59	0	1251	14.05	17577	600	2	
Automotive F-10	64.1	46.2	416	0.75	0	3920	14.05	55076	970	1.1	
G Wing											
Gymnasium	66.7	353	426	1.59	0	8936	30.41	271744	4500	1	
Boys Locker Room	66.7	353	426	1.59	0	482	9.08	4377	1375	18.9	
Lower G Wing											
JR. ROTC	65.9	446	416	1.24	0	1051	11	11561	1000	5.2	

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.

<u>Ventilation System Summary & Recommendations</u>:

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.

Burncoat High 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. Velocity (FPM)	Proposed CCM #	Proposed ECCM #	Notes
SF-B-1	B-Wing Classrooms	32820	10830	33	(25) 20x24x4	8	393	#1, #2, #3	#1 or #3	a, b, c
SF-C-1	C Wing Classrooms	36425	12384	34	(20) 24x24x4 (5) 12x24x4	8	405	#1, #2, #3	#1 or #3	a, b, c
SF-D-1	D-Wing Classroom	17560	7550	43	(16) 20x24x4	8	329	#1, #2, #3	#1 or #3	a, b, c
HV-A-1	Admin Wing	6250	N/A	20	(8) 16x25x2	8	282	#1, #2, #3	#1 or #3	a, b, c
HV-C-1	Cafeteria D Wing	4000	4000	100	N/A	8	N/A	#1, #2	#3	b, e
HV-C3/B1	Art Rooms	4000	4000	100	N/A	8	N/A	#1, #2	#3	b, e
HV-F-1/D-1	F-Wing Shops+	18,700	4,750	25	N/A	8	N/A	#1, #2, #3	#3	a, b, d
HV-G/E-1	Gym	9000	N/A	25	N/A	8	N/A	#1, #2	#3	b
HV-G/E-3	Gym	7000	N/A	25	N/A	8	N/A	#1, #2	#3	b
HV-G/E-4	Gym	7000	N/A	25	N/A	8	N/A	#1, #2	#3	b
HV-G/E-5	Gym	5400	N/A	25	N/A	8	N/A	#1, #2	#3	b

Ventilation System Summary Notes:

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

b. *To improve the ventilation effectiveness and outdoor airflow control of the classroom systems we would recommend airflow stations be added to the supply fan, return fan, outdoor airflow, and exhaust airflow of each of the five (5) units serving the classrooms, offices and such along with associated control improvements.*

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

d. *Space activities in certain shop areas may preclude the use of higher eff. filters due to the speed in which they would load. In these shops, a pre-filter may be necessitated in the return air stream of which the fan would need to be able to compensate for.*

e. *Design plans for the Café and the old Café converted to two art room reflect 100% OA. As a minimum confirm the art rooms operate in 100% OA and exhaust mode during all occupied periods.*

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 Worcester Vocational Technical High 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 Burncoat High 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.

Most of the HVAC systems supporting the Burncoat High School are capable of implementing this measure subject to outdoor ambient conditions and equipment limitations.

CCM #3 – Improved Filtration

Improve filtration to up to MERV-13 on air handling systems, especially those which recirculate air. In addition, if possible, as filters are replaced provide sealant or gasketing between and/or around filters to reduced air bypass around filter sections. Testing and balancing to confirm current airflow, pressure drops, and fan motor power coupled with manufacturer published data would be required to confirm the unit's capability for improved filtration.

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

B. ENHANCED HVAC COVID-19 CONTROL MEASURES

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

ECCM #1: Portable Room Purifiers

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

ECCM #2: UV-C Light Sterilization

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

ECCM #3: 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 Burncoat High Schools case they could be installed in the supply air duct of the respective mixed air handling systems. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Burncoat High School to address the current pandemic condition.

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

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

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

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

2) Natural Ventilation Summary

Burncoat High School

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	A HOPPER 4.47	A AWNING 4.43	B HOPPER 3.36	B AWNING 3.32	C HOPPER 4.24	D DOOR 21.00	E 3.28	F AWNING 3.97	F HOPPER 3.93	G AWNING 7.22	H HOPPER 4.28	H AWNING 9.50	I FIXED 0.00	J HOPPER 4.20	J AWNING 4.16	Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
A - Wing																						
A1 - Main Office	office	724	28.96	3															13.42	15.54	NO	
A1 - Office-1	office	101	4.04	1															4.47	-0.43	YES	
Principal's Office	office	419	16.76			4													13.44	3.32	NO	
Men's Toilet Room (in suite)	toilet room	60	2.4							1									3.28	-0.88	YES	
Women's Toilet Room (in suite)	toilet room	67	2.68							1									3.28	-0.60	YES	
Men's Toilet Room (in hallway)	toilet room	81	3.24																0.00	3.24	NO	
Women's Toilet Room (in hallway)	toilet room	78	3.12																0.00	3.12	NO	
A5 - Conference	support	295	11.8			2													6.72	5.08	NO	
A6 - Bussines Ed	classroom	1032	41.28	4															17.89	23.39	NO	
A7 - Suite	suite	295	11.8																0.00	11.80	NO	
A7- Guidance 1	office	81	3.24																0.00	3.24	NO	
A7 - Guidance 2	office	81	3.24																0.00	3.24	NO	
A7 - Guidance 3	office	81	3.24			2													6.72	-3.48	YES	
A7- Guidance 4	office	81	3.24			2													6.72	-3.48	YES	
A7 - Assistant Principal	office	168	6.72			2													6.72	0.00	YES	
A8 - Bussines Ed	classroom	1072	42.88	5															22.36	20.52	NO	
A9 - Suite	suite	452	18.08																0.00	18.08	NO	
A9 - Office 1	suite	109	4.36			2													6.72	-2.36	YES	
A9 - Office 2	office	69	2.76			2													6.72	-3.96	YES	
A9 - Office 3	office	69	2.76			2													6.72	-3.96	YES	
A-10	storage	215	8.6																0.00	8.60	NO	
Boy'r Room	toilet room	123	4.92																0.00	4.92	NO	
Girls Room	toilet room	123	4.92																0.00	4.92	NO	
A12	classroom	688	27.52			4													13.44	14.08	NO	
A14 - Bussiness Ed	classroom	738	29.52			4													13.44	16.08	NO	
A16 - Math	classroom	738	29.52			4													13.44	16.08	NO	
A18 - Reeding	classroom	788	31.52			4													13.44	18.08	NO	
B - Wing																						
B1	classroom	814	32.56			4													13.44	19.12	NO	
B2 - Math	classroom	793	31.72	4															17.89	13.83	NO	
B3	classroom	819	32.76			4													13.44	19.32	NO	
B4 - Math	classroom	819	32.76			4													13.44	19.32	NO	
B5 - English	classroom	516	20.64	2															8.94	11.70	NO	
B5 - Entry	support	124	4.96																0.00	4.96	NO	
B5A - 1	office	76	3.04																0.00	3.04	NO	
B5A - 2	office	125	5		1														4.43	0.57	NO	
B5A - 3	office	255	10.2	2															8.94	1.26	NO	
B6 - Math	classroom	820	32.8	3															13.42	19.38	NO	
B8 - Billing Ed.	classroom	739	29.56			5													16.81	12.75	NO	
B9 - English	classroom	715	28.6			5													16.81	11.79	NO	
B10 - Science	classroom	1017	40.68		5														22.16	18.52	NO	
B11 - English	classroom	820	32.8			4													13.44	19.36	NO	
B12 - Science Support	support office	290	11.6		4														17.73	-6.13	YES	
B12A - Science Support	support office	296	11.84																0.00	11.84	NO	
B14 - Science	classroom	1057	42.28		5														22.16	20.12	NO	
B15 - Billing Ed.	classroom	271	10.84				2												6.65	4.19	NO	
B16 - Cafeteria	cafeteria	2171	86.84	6															26.83	60.01	NO	
B17 - Math	classroom	715	28.6			4													13.44	15.16	NO	
B19 - Suite	office	357	14.28		2														8.86	5.42	NO	
B19 - Asst. Principal	office	173	6.92		2														8.86	-1.94	YES	
B19 - Guidance -1	office	79	3.16																0.00	3.16	NO	
B19 - Guidance -2	office	78	3.12																0.00	3.12	NO	
B - Men's Teacher Lounge	lounge	231	9.24			2													6.72	2.52	NO	
B - Teacher's Lounge	lounge	455	18.2	4															17.89	0.31	NO	
B - Women's Teacher Lounge	lounge	238	9.52			2													6.72	2.80	NO	
B - Kitchen	kitchen	2452	98.08																0.00	98.08	NO	

C - Wing																					
C - Art Storage	storage	380	15.2																0.00	15.20	NO
C1A - Art	classroom	1152	46.08	1															4.47	41.61	NO
C1B - Art	classroom	1075	43	5															22.36	20.64	NO
C2 - Computer Lab	classroom	816	32.64				4												13.29	19.35	NO
C3 - Physics	classroom	1079	43.16		3														13.30	29.86	NO
C - Girls Room	toilet room	206	8.24																0.00	8.24	NO
C - Boys Room	toilet room	278	11.12				2												6.65	4.47	NO
C4 - Computer Lab	classroom	822	32.88			4													13.44	19.44	NO
C5 - Physics	classroom	1032	41.28		2		4												22.16	19.12	NO
C5 - Physics Storge	storage	172	6.88																0.00	6.88	NO
C6 - Social Studiews	classroom	822	32.88			4													13.44	19.44	NO
C7	office	363	14.52				3												9.97	4.55	NO
C8 - Word Language	classroom	822	32.88			4													13.44	19.44	NO
C9	classroom	716	28.64			3													10.08	18.56	NO
C10 - Storage	storage	154	6.16																0.00	6.16	NO
C11	office	408	16.32																0.00	16.32	NO
C12 - World Language	classroom	862	34.48			4													13.44	21.04	NO
C14 - Content Mastery	classroom	709	28.36			3													10.08	18.28	NO
C17 - Library	library	2019	80.76	4		7													41.42	39.34	NO
C17 - Library Office	office	205	8.2		1														4.43	3.77	NO
C19 - World Language	classroom	826	33.04			4													13.44	19.60	NO
C21 - World Language	classroom	812	32.48			3													10.08	22.40	NO
D - Wing																					
D1	classroom	874	34.96			5													16.81	18.15	NO
D2 - Social Studies	classroom	816	32.64			4													13.44	19.20	NO
D3	classroom	819	32.76			4													13.44	19.32	NO
D4- English	classroom	819	32.76			4													13.44	19.32	NO
D5	classroom	787	31.48			4													13.44	18.04	NO
D6 - Spec Ed	classroom	605	24.2		1									3					17.27	6.93	NO
D6A - Spec Ed	classroom	615	24.6											3					12.83	11.77	NO
D7- Cafeteria	cafeteria	2491	99.64																0.00	99.64	NO
D8 - ESL	classroom	819	32.76			4													13.44	19.32	NO
D10 - Suite	office	536	21.44																0.00	21.44	NO
D10 - Guidance 1	office	63	2.52			1													3.36	-0.84	YES
D10 - Guidance 2	office	63	2.52			1													3.36	-0.84	YES
D10 - Assist Principal	office	133	5.32			2													6.72	-1.40	YES
D - Boys Room	toilet room	162	6.48																0.00	6.48	NO
D - Women's Room	toilet room	164	6.56																0.00	6.56	NO
D14 - Health	classroom	737	29.48			4													13.44	16.04	NO
D16 - Math	classroom	741	29.64			4													13.44	16.20	NO
D18 - Science	classroom	736	29.44		3		1												16.62	12.82	NO
D20 - Science	classroom	1058	42.32		4														17.73	24.59	NO
D22 - Office	support	249	9.96													3			0.00	9.96	NO
D24 - Science	classroom	1048	41.92		3		1												16.62	25.30	NO
D24 - Office	office	264	10.56																0.00	10.56	NO
D - Girl's Room	toilet room	119	4.76																0.00	4.76	NO
D - Boy's Room	toilet room	129	5.16																0.00	5.16	NO
E - Wing																					
E1 - Horticulture	classroom	1114	44.56				5												16.61	27.95	NO
E2 - English	classroom	889	35.56	3															13.42	22.14	NO
E3 - Art	classroom	1134	45.36				5												16.61	28.75	NO
E4 - Social Studies	classroom	1033	41.32	3		1													16.78	24.54	NO
E4 - Storage	Storage	97	3.88		1														4.43	-0.55	YES
E5	classroom	521	20.84				2												6.65	14.19	NO
E6 / 8 - Home Eco	classroom	2226	89.04	2	5									1						38.33	50.71	NO
E7	classroom	630	25.2				3												9.97	15.23	NO

F - Wing

F2 - Social Studies	classroom	760	30.4				3																								1			17.50	12.90	NO	
F4 - Tech Drawing	classroom	1062	42.48				4																											17.73	24.75	NO	
F6 - Graphic Arts	classroom	1251	50.04				2																											8.86	41.18	NO	
F6 - Office	office	150	160																															0.00	160.00	NO	
F6 - Dark Room	classroom	79	3.16																															0.00	3.16	NO	
F10 - Automotive	classroom	3920	156.8				6																											26.59	130.21	NO	
F10 - Office	office	172	6.88																															0.00	6.88	NO	
F14 - Quinsig Auto	classroom	1109	44.36				2																											8.86	35.50	NO	
F14 - Office	office	115	4.6				1																											4.43	0.17	NO	
F14 - CAD Technology	classroom	593	23.72																															0.00	23.72	NO	
F14 - Office	office	168	6.72																															0.00	6.72	NO	
F - Upper Boiler Room - Office	office	267	10.68				1																											4.43	6.25	NO	
F - Upper Boiler Room - Tiolet	toilet room	106	4.24				1																											4.43	-0.19	YES	

G - Wing

G - Women's Room	toilet room	75	3										1																					4.24	-1.24	YES	
G - Men's Room	toilet room	85	3.4										1																					4.24	-0.84	YES	
G - Girl's Exercise Room	gym	342	13.68										3																					12.72	0.96	NO	
G - Girl's Locker Room	gym	429	17.16										3																					12.72	4.44	NO	
G - Girls Toilet Room	toilet room	158	6.32										1																					4.24	2.08	NO	
G - Old Shower Room	gym	1783	71.32										4																					16.96	54.36	NO	
G - Girl's Visitor Lockerroom	gym	559	22.36																															0.00	22.36	NO	
G - Girl's Office	office	67	2.68																															0.00	2.68	NO	
G - Boy's Office 1	office	187	7.48																															0.00	7.48	NO	
G - Boy's Office 2	office	154	6.16																															0.00	6.16	NO	
G - Boy's Drying and Shower	gym	559	22.36																															0.00	22.36	NO	
G - Boy's Visitor Lockeroom	gym	473	18.92										5																					21.20	-2.28	YES	
G - Office 3 / Storage	office	203	8.12										1																					4.24	3.88	NO	
G - Boy's Old Wight Room	gym	544	21.76										4																					16.96	4.80	NO	
G - Boy's Freshman Lockerroom	gym	256	10.24										4																					16.96	-6.72	YES	
G - JR ROTC Classroom	classroom	579	23.16				3																											13.30	9.86	NO	
G - JR ROTC Support	classroom	1051	42.04				5																											22.16	19.88	NO	

Window Type	Width	Hieght	Projection	Venting
A - Hopper	41	15	11.5	4.47
A - Awning	41	14.5	11.5	4.43
B - Hopper	29	15	11	3.36
B - Awning	29	14.5	11	3.32
C - Hopper	41	14.5	11	4.24
D - Door	36	84	-	21.00
E - High Hopper	29	14	11	3.28
F - Hopper	37	15	11	3.97
F - Awning	37	14.5	11	3.93
G - Awning	22	30	20	7.22
H - Hopper	41	15	11	4.28
H - Awning	42	30	19	9.50
I - Fixed	0	0	0	0.00
J - Hopper	40	15	11	4.20
J - Awning	40	14.5	11	4.16

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)