Worcester Public Schools

Ventilation Assessment
&
COVID-19
Mitigation Strategies

for

Doherty High School
Worcester, MA

January 31, 2021

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Worcester Public Schools

A. Preface:

Worcester Public School has as Nault Architects Inc. and their consultant Seaman Engineering Corporation (SEC) to review all of their occupied buildings and comment on existing natural and mechanical ventilation.

The first part of the report is SEC's evaluation of the existing mechanical systems.

The second part of the report is an evaluation of the natural ventilation. The Building Code requires ventilation of each occupied space and that can be achieved either through mechanical 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 Doherty Quadrant of Worcester at 299 Highland Street. The School was built in 1966, houses grades 9-12, has 84 classrooms and the building is 168,136 square feet. The widows are orignal to the school and many are not fully functional.

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 Doherty 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 where possible. For enhanced measures WPS has begun to incorporate Bipolar Ionization (see ECCM-#3) extensively throughout the Doherty High 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 Doherty 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 classroom HVAC systems supporting the Doherty High School are very close to meeting the 3 ACH requirement with some areas just below and others above. The gymnasium, auditorium and music room 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 they already provide 100% outside air and are at their systems 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.

Except for potentially the auditorium air handling system, most of the existing HVAC systems will not support increased filtration above MERV 8 either due to physical equipment limitations (i.e., fan coils 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.

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 Doherty 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 Doherty 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 Doherty High School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
General Classrooms	Energy Recovery Units (CUV in music)	CCM - #1 CCM - #2 may be applied in music room. ECCM - #1 or #3 (*see note below)
Science Classrooms	Energy Recovery Units	Increase O.A. ventilation to code minimum. CCM - #1 & #2; ECCM - #3
Art Classrooms	Energy Recovery Units	Increase O.A. ventilation to code minimum. CCM - #1 & #2; ECCM - #3
Auditorium	Air Handler & Energy Recovery Unit	CCM - #1, #2 & #3 ECCM - #2 or #3
Gymnasium	Air Handlers	CCM - #1 & #2 ECCM - #3
Admin. & Guidance Office	None	The current administration and guidance offices have little or no outdoor air ventilation. These areas should be provided with outdoor ventilation air to comply with current code requirements. CCM - #1, #2 & #3 ECCM - #1 or #3 (*see note below)

*<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) 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.

General Classrooms:

A majority of the classrooms in the building are heated with 2-pipe fan coil units. These units are fed with hot water from the central boiler 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 recirculate heated or neutral air within the room they serve. A DDC space thermostat controls the operation of the hydronic valve in the units as well as the fan with occupied and unoccupied schedules. The fan coils appear to be programmed for continuous fan mode during occupied periods with 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.

Outdoor air for most of the classroom spaces is supported by eleven (11) packaged rooftop energy recovery units supporting dedicated outdoor air systems (DOAS). The units are identified as ERV-A, B, D thru H and ERV-L thru O. These units are configured as 100% outside air systems with no recirculation air. The units have intake dampers, filter sections, total energy recovery wheels, gas-fired furnaces, exhaust fans and supply fans. The units have 2" thick pleated filters with an estimated MERV rating of 8.

These ERV units may be able to support improved filtration of MERV 11 or potentially even MERV 13 however, any improvement in filtration must be confirmed thru unit airflow testing to evaluate if the unit can support the added pressure drop from higher filtration without risk of reducing airflow. As these unit's convey 100% outside air, they not filtering contaminated space air but only outside air and as such the space air quality would not benefit greatly by increasing filtration at the risk of a potential reduction in air volume from higher pressure drop faster loading higher MERV filters.

The system delivers approx. 400 CFM of outdoor air directly to most typical classroom spaces. The system also exhausts 275 CFM from each room thereby placing the rooms under a slight positive pressure.

There are also several classroom and other rooms such as choir, graphic arts, etc.… which are supported by unit ventilators. 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 water valve, face & bypass dampers (where applicable) and mixing dampers to maintain space temperature setpoint.

Where unit ventilators are present, exhaust is generally supported by roof exhaust fans connecting to the supporting rooms via above ceiling ductwork and vertical duct chases. The exhaust fans appear to exhaust just the minimum amount of outside air for ventilation and are not sized to exhaust 100% outside air which occurs when the unit ventilators go into free cooling/economizer mode.

For a standard classroom, current code would require 10 CFM per person of outside air plus 0.12 CFM per SF. For a system with a zone air distribution effectiveness of 1.0, as most classrooms with the current DOAS systems are, a room size of 800 SF with 26 occupants (25 students + 1 teacher) would require 356 CFM of outdoor. Hence the current systems operating at 400 CFM provide more than the code required outdoor air to the rooms.

Science & Art Rooms:

The science and art room areas are supported by the same types of fan coil units and outdoor air systems which supply the normal classroom systems. These rooms are supplied with the same 400 CFM of outside air as the standard classrooms. The system also exhausts 500 CFM from each of the science rooms thereby placing the rooms under a slight negative pressure.

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 these rooms may be non-compliant, especially if they are actual labs with fume hoods which would require added make-up air when the hoods are operational. If the rooms are not used as labs lower typical classroom ventilation levels may apply.

Bathroom and local exhaust requirements not addressed by the ERV systems are supported by roof mounted centrifugal exhaust fans. These exhaust systems appear to meet or exceed the current ventilation codes for the spaces serviced.

Cafeteria:

Outdoor air for the cafeteria space is supported by one (1) packaged rooftop energy recovery unit labeled ERV-C. The unit is configured as a 100% outside air system with no recirculation air. The unit has intake dampers, filter sections, total energy recovery wheel, gas-fired furnace, exhaust fan and supply fan. The unit has 2" thick pleated filters with an estimated MERV rating of 8. The unit is rated for 2,800 CFM of outdoor air and exhaust air.

As noted with the ERV units for the classrooms, this unit may be able to support improved filtration pending unit airflow testing to evaluate the unit's capabilities. However, as this unit

conveys 100% outside air, it is not filtering contaminated space air but only outside air and as such the space air quality would not benefit greatly by increasing filtration at the risk of a potential reduction in air volume from higher pressure drop faster loading higher MERV filters.

The cafeteria system is heated via perimeter fin-tube radiation. HVAC systems within the space are controlled by building EMS system.

For a cafeteria current code would require 7.5 CFM per person of outside air plus 0.18 CFM per SF. For a system with a zone air distribution effectiveness of 1.0, as this type of DOAS system would be, the existing cafeteria which encompasses approx. 4,368 SF would be able to accommodate up to 268 occupants.

Media Center & Offices:

The media center, adjoining classrooms as well as the nurse's office outdoor air needs appear to be supported by a packaged rooftop energy recovery unit labeled ERV-O. The unit is configured as a 100% outside air system with no recirculation air. The unit has intake dampers, filter sections, total energy recovery wheel, gas-fired furnace, exhaust fan and supply fan. The unit has 2" thick pleated filters with an estimated MERV rating of 8.

As noted with the ERV units for the classrooms, this unit may be able to support improved filtration pending unit airflow testing to evaluate the unit's capabilities. However, as this unit conveys 100% outside air, it is not filtering contaminated space air but only outside air and as such the space air quality would not benefit greatly by increasing filtration at the risk of a potential reduction in air volume from higher pressure drop faster loading higher MERV filters.

Existing drawings do not properly reflect this area, so the presumption is that ERV-O serves the media center, adjacent classrooms and possibly (routing not confirmed) the nurse's area ducted system on the floor below. The main office area has no positive outside air ventilation other than that afforded by operable windows where available. These areas are supported by ductless split style heat pump units for cooling and heating. Perimeter fin-tube radiation is also provided on exterior exposure walls for supplemental heating.

From the plans, it appears that the media center was designed for 900 CFM of outside air. For a space such as this 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 this type of DOAS system would be, the existing media center which, encompasses approx. 2,822 SF would be able to accommodate up to 56 occupants.

Gymnasium & Auditorium:

The auditorium is heated and ventilated through the use of a central air handler located within the boiler room. The air handler is fitted with a mixing box, filter section, hot water coil and fan. Originally the system brought outdoor air in through a roof vent and exhausted

the space via a roof mounted exhaust fan. However, during a renovation project, the outdoor air for the space was upgraded to incorporate a one (1) packaged rooftop energy recovery unit labeled ERV-P. The unit is configured as a 100% outside air system with no recirculation air. The unit has intake dampers, filter sections, total energy recovery wheel, gas-fired furnace, exhaust fan and supply fan. The filters on both the air handler and ERV unit are 2" thick pleated filters with an estimated MERV rating of 8.

The filters for the auditorium air handler should 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.

For the media center ERV, as was noted with the ERV units for the classrooms, this unit may be able to support improved filtration pending unit airflow testing to evaluate the unit's capabilities. However, as this unit conveys 100% outside air, it is not filtering contaminated space air but only outside air and as such the space air quality would not benefit greatly by increasing filtration at the risk of a potential reduction in air volume from higher pressure drop faster loading higher MERV filters.

From the design drawings it appears that the auditorium ERV-P unit was designed for 4,600 CFM of outside air. For a space such as this current code would require 5 CFM per person of outside air plus 0.06 CFM per SF for the main area and 10 CFM per person plus 0.06 CFM per SF for the stage area. The zone air distribution effectiveness of this system was presumed as 1.0, as the return air is low, and the supply air temperature should be limited due to the low space heating demand. With 100 occupants on the stage the system could support approx. 600 occupants within the main auditorium space.

The gymnasium spaces are served by vertical wall mounted ducted heating and ventilation units. Each unit is fitted with a mixing box, filter section, hot water coil and supply fan. Filter size and capacity could not be determined due to the elevated location of the units however, based on their age and type we expect the maximum filtration level that could be obtained would be MERV 8.

The original plans for the gymnasium systems inferred approximately 1,800 CFM of outside air for each unit in the large gym however, the unit size varies for the smaller gym. In addition, control drawings reflect a minimum outdoor air percentage of 15% which would be far below the plan indicated 1,800 CFM.

The control drawings for both the gymnasium systems and the auditorium systems reflect the utilization of occupancy sensors to enable occupied modes of operation. In addition, both the gym and auditorium systems reflect CO_2 sensors however, the gymnasium systems reflect outdoor air demand ventilation reset off of space CO2 whereas this is not clear for the auditorium system. In addition, the control drawings make no reference of the ERV unit coupled to the auditorium system. We suspect the controls have been upgraded to support this.

Controls:

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 Automated Building Systems, Inc (ABS). Although a further review with the EMS vendor would be required to ascertain the extent of this system it is our current understanding that the system controls all the rooftop ERV units as well as most of the fan coil units, unit ventilators, exhaust fans, etc.… Many of the packaged ERV units have factory furnished controls which control much of their internal operation with the EMS simply commanding occupied, unoccupied modes and potentially resetting temperatures.

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.

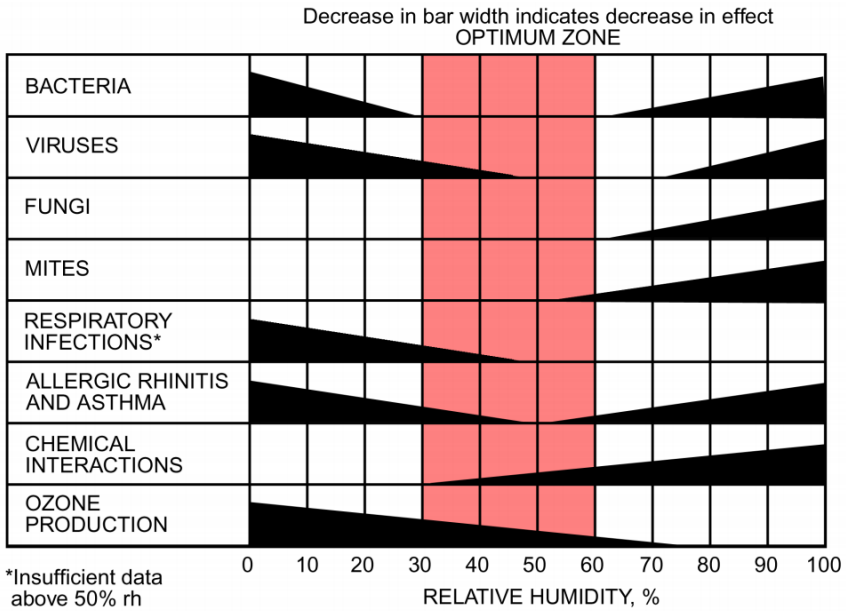

Fig. 1 Optimum Humidity Range for Human Comfort and Health
(Adapted from Sterling et al. 1985)

The Doherty High School HVAC systems have no active humidity control. However, most of the classroom spaces are served by ventilation units which have energy recovery wheels that transfer moisture generated by occupants and activity within the space back into the incoming outdoor air during the cold winter months. This moisture exchange aids in providing some moisture into the dry outdoor air stream dependent on exterior conditions and space occupancy. For spaces that are air conditioned, the energy wheels can also assist in removing moisture from incoming summer air to aid in space 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.

Other than the humidity transfer through the energy recovery ventilation units, 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 Doherty High School often have poor vapor barriers, if any, as well as unique wall and window construction and thermal characteristics that 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 Doherty High School have a design outdoor air exchange rate of 3 or above meeting 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.

Doherty High School IAQ Sampling Summary

Space Tested	Temp. °F	Humidity % RH	CO2 ppm	TVOC ppm	HCHO ppm	Room Area SqFt	Room Ht. Ft	Volume Cubic Feet	Original Design OA CFM	Original OA Air ACH	Notes
100 Series Wing											
Instrumental Room	72.9	40	505	0.47	0	1435	9.83	14106	500	2.1	
Auditorium	71.2	40.9	490	0.37	0	6667	19.58	130540	4600	2.1	
Main Office	72.8	42.1	628	1.35	0.18	905	8.92	8073	0	0	1, 3
Guidance Reception	73.2	41.5	633	1.33	0.18	482	8.92	4299	0	0	1, 3
Business Room 107	73	37.7	461	0.3	0	1057	8.83	9333	375	2.4	
School Nurse Waiting	72.5	36.7	601	1.43	0.26	68	8.08	549	0	0	1
Cafeteria	73	37	443	0.22	0	4317	8.83	38119	2800	4.4	
Kitchen	72	38.4	448	0.31	0	2008	9.25	18574	5400	17.4	
200 Series Wing											
Art Room 204	72.3	43.3	554	0.66	0.02	1076	8.42	9060	400	2.6	
Media Center	72.3	40	485	0.72	0	2800	8.42	23576	900	2.3	
Family & Consumer Science Rm	72.7	40.5	474	0.57	0	1229	8.42	10348	400	2.3	
300 Series Wing											
Classroom Rm 332	69.9	43	477	0.26	0	735	9	6615	400	3.6	
Science Rm 324	69.7	44.1	471	0.19	0	1052	8.83	9289	400	2.6	
Teachers Rm 313a	70.9	43.2	528	0.53	0	305	9	2745	400	8.7	
Reception Rm 309	71.7	41.6	499	1.37	0.31	173	9	1557	0	0	1
Classroom rm 307	71.4	41.2	505	0.35	0	817	9	7353	400	3.3	
Wood Shop Rm 302A	71.4	42.2	494	1.09	0	1200	12.17	14604	375	1.5	2
Graphic Arts Rm 302B	68.9	43.7	474	1.3	0	861	8.33	7172	250	2.1	2
Science Engineering Lab Rm 304	70.8	44.5	469	0.81	0	866	8.42	7292	unknown		
400 Series Wing											
Classroom Rm 411	71.9	39.6	460	0.17	0	712	8.42	5995	400	4	
Classroom Rm 418	71.7	41.6	461	0.35	0	821	8.42	6913	400	3.5	
Classroom Rm 426	69	44.1	474	0.33	0	717	8.42	6037	400	4	
Gymnasium											
Large Gym	69.4	43.3	476	0.43	0	7196	25.58	184074	7200	2.3	
Girls Locker Room	69.2	41.2	477	0.53	0	574	19.58	11239	500	2.7	

IAQ Summary Table Notes:

1. *TVOC's and CH_2O higher than anticipated for an office type space. Suggest further review of ventilation systems serving the areas and review of cleaners used.*
2. *Elevated TVOC levels in the wood shop and graphic arts may be due to, paints, cleaners and various building products located in the space. Suggest further review of ventilation systems serving the areas for improved dilution as well as review of possible mitigation of sources.*
3. *These areas have no active outdoor air ventilation system which may be a contributing factor for the elevated CO2, TVOC and HCHO readings.*

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.

In addition, to the below recommended measures, we also highly recommend that ventilation air be provided in the administration office areas to support required ventilation levels. In the immediate interim he would highly recommend portable air filtration units (see ECCM #1) also be installed.

Doherty 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. (FPM)	Proposed CCM #	Proposed ECCM #	Notes
ERV-A	CR 300 & 400 Wing West(409,319...)	3000	3000	100	(3) 20x25x2	8	288	1	1, 3	a
ERV-B	CR 300 & 400 Wing West(424,330...)	3200	3200	100	(3) 20x25x2	8	307	1	1, 3	a
ERV-C	Cafeteria	2800	2800	100	(3) 20x25x2	8	269	1	1, 3	b
ERV-D	CR 200 Wing Upper Level West	2850	2850	100	(3) 20x25x2	8	274	1	1, 3	a
ERV-E	CR 300 Wing Ctr (315,324,326,328)	1200	1200	100	(2) 20x20x2	8	216	1	1, 3	a
ERV-F	CR 300 & 400 Wing Ctr (415,313...)	4250	4250	100	(3) 20x25x2	8	408	1	1, 3	a
ERV-G	CR 400 Wing Center (410,411...)	2450	2450	100	(3) 20x25x2	8	235	1	1, 3	a
ERV-H	CR 300 Wing Center (316,318...)	1950	1950	100	(3) 20x25x2	8	187	1	1, 3	a
ERV-L	CR 300 & 400 Wing East (406,312...)	2700	2700	100	(3) 20x25x2	8	259	1	1, 3	a
ERV-M	CR 300 & 400 Wing East (404,309...)	2550	2550	100	(2) 20x20x2	8	459	1	1, 3	a
ERV-N	CR 300 & 400 Wing East (402,305...)	2200	2200	100	(3) 20x20x2	8	211	1	1, 3	a
ERV-O	Media Center and adj. classrooms	4600	4600	100	(6) 16x20x2	8	345	1	1, 3	b
ERV-P	Auditorium	4600	4600	100	(6) 16x20x2	8	345	1, 2, 3	2, 3	c, d
(2) HV	Small Gym	(2)2500	unknown	?				1, 2	3	d
(4) HV	Large Gym	(4)3500	(4)1800	51%				1, 2	3	d

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. *For the cafeteria and media center ECCM #1 – Portable Air Filtration is noted as a possible option to improve air cleaning and changeover during pandemic conditions. It shall be noted that multiple units would be recommended in each due to the large spaces.*

c. *For the auditorium CCM #2 – Increased Ventilation is recommended as the current system appears to have the original outdoor air intake which could work in conjunction with the ERV for increase ventilation. CCM # 3 - Improved Filtration is predicated on the unit being able to support such filtration. ECCM #2 – UV-C Light Sterilization may be effective due to the extended length of return air duct to allow installation of such.*

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

II. COVID-19 HVAC MITIGATION MEASURES

A. HVAC COVID-19 CONTROL MEASURES

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

The ASHRAE Epidemic Task Force recommends several measures to assist in COVID-19 mitigation with more aggressive action with epidemic conditions in place (ECiP) and post-epidemic conditions in place (P-ECiP). For ECiP conditions in place the HVAC COVID-19 Control Measures (CCM) that could be readily applied to the Doherty 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.

CCM #1 – Pre & Post Purge

Pre- and post-purge ventilation of occupiable spaces using outside air introduced the HVAC systems. This would be accomplished by starting the ventilation systems in occupied mode (i.e., OA at design or higher) 4 hours prior to schedule building occupancy and maintain the occupied mode for 4-hours after occupancy ends.

Most of the HVAC systems supporting the Doherty High School are capable of implementing this measure.

CCM #2 – Increased Ventilation

Increase outdoor air ventilation for improved space dilution where systems allow. This would entail increasing the minimum outdoor air damper positions on all mixed air style systems within the limits of the equipment capacity and overriding any demand ventilation reset schemes (i.e., 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 gymnasium, auditorium and music room HVAC systems have the ability to increase outdoor air for increase outdoor air ventilation and air change rate. Many of the classrooms HVAC systems throughout the building cannot support this measure as they already provide 100% outside air and are at their design capacity.

CCM #3 – Improved Filtration

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

Higher filtration on 100% outdoor air systems is not as critical as they do not recirculate space air albeit improved filtration possibly as high as MERV 11 may be considered subject to unit fan capabilities. Most, room terminal 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 manuf. published data would be required to confirm the unit's capability for improved filtration.

B. ENHANCED HVAC COVID-19 CONTROL MEASURES

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

ECCM #1: Portable Room Purifiers

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

ECCM #2: UV-C Light Sterilization

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

ECCM #3: Bi-Polar Ionization

Air ionizers are meant to be installed in the supply air duct or plenum downstream of fans and filters. They are also offered as portable units for room application. In Doherty High Schools case they could be installed in the supply air duct of the respective mixed air handling systems as well as the dedicated outdoor air systems. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Doherty 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 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

Doherty High School

Room Name / Number	Space Use	Net Floor Area (SF)	4% of Net Area	Number of windows by Type														Total open Area (SF)	Difference between actual and required SF	PASS?	Additional Notes
				B HOPPER	2.81	C AWNING	6.14	D FIXED	0.00	E HOPPER	4.05	F FIXED	0.00	J MIXED	12.06	L HOPER	3.47				
100 Wing - First Floor																					
Main Office	office	892	35.68														6	20.81	14.87	NO	
Main Office - Principal	office	259	10.36														3	10.41	-0.05	YES	
Main office - Safe	office	93	3.72															0.00	3.72	NO	
Main Office - I/O Clerk	office	258	10.32														3	10.41	-0.09	YES	
Main Office - Assist Prin Recp	office	236	9.44															0.00	9.44	NO	
Main Office - Assist Principal 1	office	85	3.4														2	6.94	-3.54	YES	
Main Office - Assist Principal 2	office	85	3.4														2	6.94	-3.54	YES	
Main Office - Admin Room 1	office	79	3.16															0.00	3.16	NO	
Main Office - Admin Room 2	office	79	3.16															0.00	3.16	NO	
Guidance Reception	office	482	19.28														4	13.88	5.41	NO	
Guidance Room 01	office	86	3.44														2	6.94	-3.50	YES	
Guidance Room 02	office	98	3.92														2	6.94	-3.02	YES	
Guidance Copier Room	office	116	4.64															0.00	4.64	NO	
Guidance Room 03	office	79	3.16															0.00	3.16	NO	
Guidance Room 04	office	79	3.16															0.00	3.16	NO	
Guidance Room 05	office	80	3.2															0.00	3.20	NO	
Guidance Room 06	office	80	3.2															0.00	3.20	NO	
Guidance Career Center - Room 105	office	870	34.8														6	20.81	13.99	NO	
Bussiness Room 106	classroom	984	39.36														7	24.28	15.08	NO	
Bussiness Room 107	classroom	982	39.28														7	24.28	15.00	NO	
Cafeteria	café	4318	172.72														28	97.13	75.60	NO	
Kitchen	kitchen	2008	80.32								8							32.39	47.93	NO	
Kithcen - Office	office	78	3.12															0.00	3.12	NO	
Kitchen - Dishwasher	kitchen	298	11.92															0.00	11.92	NO	
Teacher's Dinning - Room 110	dining	495	19.8								5							20.24	-0.44	YES	
Girls Room	toilet	119	4.76															0.00	4.76	NO	
Boys Room	toilet	121	4.84															0.00	4.84	NO	
Health Center - Room 109																		0.00	0.00	NO	
Health Center - Reception	health	124	4.96															0.00	4.96	NO	
Health Center - Exam 1	health	100	4								2							8.10	-4.10	YES	
Health Center - Office 1	health	46	1.84								1							4.05	-2.21	YES	
Health Center - Office 2	health	46	1.84								1							4.05	-2.21	YES	
Health Center - Exam 2	health	89	3.56								2							8.10	-4.54	YES	
Health Center - Pysch Room 108	health	119	4.76								1							4.05	0.71	NO	
Women's Room	toilet	120	4.8		1													2.81	1.99	NO	
Men's Room	toilet	120	4.8		1													2.81	1.99	NO	
Custodiam office	office	238	9.52															0.00	9.52	NO	
Spec Ed Room B-D - Room 104	classroom	761	30.44														5	17.34	13.10	NO	
Music Practice - 01	classroom	43	1.72															0.00	1.72	NO	
Music Practice - 02	classroom	41	1.64															0.00	1.64	NO	
Music Practice - 03	classroom	40	1.6															0.00	1.60	NO	
Music Preactice - 04	classroom	54	2.16															0.00	2.16	NO	
B14 - Science	classroom	1057	42.28														1	3.47	38.81	NO	
Choral Room - Room 103	classroom	973	38.92														4	13.88	25.05	NO	
Music Storage - Room 102	storage	311	12.44															0.00	12.44	NO	
Instrumental Room - 101	classroom	1435	57.4														7	24.28	33.12	NO	
Instrumental Room - Storage	storage	168	6.72															0.00	6.72	NO	
Instrumental Room - Uniform	storage	88	3.52															0.00	3.52	NO	
Auditorium / Stage	aud	4675	187															0.00	187.00	NO	

200 Wing - Second Floor																			
Rm 200 - Faculty Conference	office	442	17.68											4	13.88	3.81	NO		
Rm 201 - Adio / Visual	classroom	320	12.8	2											5.63	7.18	NO		
Rm 202	classroom	608	24.32											3	10.41	13.91	NO		
Rm 202A - Editing	classroom	150	6												0.00	6.00	NO		
Rm 202B - Studio	classroom	245	9.8											3	10.41	-0.61	YES		
Rm 203 - Computer	classroom	307	12.28	2											5.63	6.66	NO		
Rm 204 - Art	classroom	1075	43											13	45.09	-2.09	YES		
Rm 205 - Spec Ed	classroom	1059	42.36											13	45.09	-2.73	YES		
Rm 206 - Comp Lab	classroom	715	28.6											7	24.28	4.32	NO		
Rm 207 - Comp Lab	classroom	708	28.32											7	24.28	4.04	NO		
Rm 208	classroom	717	28.68											7	24.28	4.40	NO		
Rm 209 - Spec Ed	classroom	715	28.6											7	24.28	4.32	NO		
Rm 210	classroom	728	29.12											7	24.28	4.84	NO		
Storage Room	storage	249	9.96	2											5.63	4.34	NO		
Rm 211 - Family & Cons Science	classroom	1229	49.16											8	27.75	21.41	NO		
Rm 212A - Child Study	classroom	412	16.48											4	13.88	2.61	NO		
Rm 212B - Child Study	classroom	813	32.52											7	24.28	8.24	NO		
Rm 212B - Child Study Kitchen	kitchen	214	8.56												0.00	8.56	NO		
Girls Room	toilet	221	8.84	1											2.81	6.03	NO		
Boys Room	toilet	220	8.8	1											2.81	5.99	NO		
Media Center	classroom	2784	111.36											29	100.59	10.77	NO		
Media Center - Office	office	236	9.44												0.00	9.44	NO		
300 Wing - First Floor																			
In House Suspension Room	support	1397	55.88											3	10.41	45.47	NO		
In House Suspension Rm - Storage	storage	131	5.24												0.00	5.24	NO		
Shop Storage	support	459	18.36											4	13.88	4.49	NO		
Maintence Garage	support	143	5.72											4	13.88	-8.16	YES		
Rm 300 - Fabrication Photo Lab	classroom	640	25.6												0.00	25.60	NO		
Rm 302A - Grapgics Arts Lab	classroom	1200	48											7	24.28	23.72	NO		
Rm 302A - Copy	copy	159	6.36												0.00	6.36	NO		
Rm 302A - Storage	storage	143	5.72												0.00	5.72	NO		
Rm 302B - Graphics Arts	classroom	860	34.4											3	10.41	23.99	NO		
Rm 302B - Office	office	158	6.32												0.00	6.32	NO		
Rm 302B - Storage	storage	124	4.96												0.00	4.96	NO		
Rm 303 - Science Eng Lan	classroom	951	38.04											2	6.94	31.10	NO		
Rm 303 - Storage	storage	150	6												0.00	6.00	NO		
Rm 304A - Science Eng Lab	classroom	865	34.6		6										36.83	-2.23	YES		
Rm 304B - Comp Lab	classroom	756	30.24		1										6.14	24.10	NO		
Men's / Storage	toilet / storage	266	10.64		2										12.28	-1.64	YES		
Rm 305	classroom	826	33.04		4										24.56	8.48	NO		
Rm 306	classroom	875	35											9	31.22	3.78	NO		
Rm 307	classroom	817	32.68		6										36.83	-4.15	YES		
Rm 308	classroom	797	31.88											8	27.75	4.13	NO		
Rm 309 - Reception	office	173	6.92												0.00	6.92	NO		
Rm 309A - Spec Ed Vis Imp	classroom	150	6												0.00	6.00	NO		
Rm 309B - Asst Principal	office	189	7.56												0.00	7.56	NO		
Rm 309C - Asst Principal	classroom	145	5.8												0.00	5.80	NO		
Rm 309D - Fac Conf	conference	406	16.24												0.00	16.24	NO		
Faculty Fitness	support	250	10		1										6.14	3.86	NO		
Faculty Fitness - Toilet Rm	toilet	27	1.08		1										6.14	-5.06	YES		
Boys Room	toilet	225	9	1											2.81	6.19	NO		
Girls Room	toitlet	219	8.76	1											2.81	5.95	NO		
Rm 310	classroom	801	32.04											8	27.75	4.29	NO		
Rm 311	storage	363	14.52												0.00	14.52	NO		
Rm 312	classroom	801	32.04											8	27.75	4.29	NO		
Rm 32	storage	363	14.52												0.00	14.52	NO		
Rm 313A - Teacher's Rm	support	304	12.16		2										12.28	-0.12	YES		
Rm 313A - Teacher's Rm - Mens	toilet	50	2		1										6.14	-4.14	YES		
Rm 313B - Teacehr's	support	301	12.04		3										18.42	-6.38	YES		
Rm 313C - Teacher's	support	296	11.84		2										12.28	-0.44	YES		
Rm 313C - Teacher's - Womens	storage	48	1.92		1										6.14	-4.22	YES		
Rm 314	office	840	33.6											7	24.28	9.32	NO		
Rm 315 - Physics Prep	classroom	1027	362		6									6	57.65	304.35	NO		
Rm 316 - Science	classroom	1027	41.08											6	20.81	20.27	NO		
Boys Room	toilet	218	8.72	1											2.81	5.91	NO		
Girls Room	toilet	218	8.72	1											2.81	5.91	NO		
Rm 317	classroom	616	24.64		4										24.56	0.08	NO		
Rm 317A - Math Lab	classroom	271	10.84		2										12.28	-1.44	YES		
Rm 318 - Science	classroom	1052	42.08											7	24.28	17.80	NO		
Rm 319	classroom	768	30.72		4										24.56	6.16	NO		
Rm 320 - Science	classroom	1045	41.8											7	24.28	17.52	NO		
Rm 321A - Spec Ed - L.D.	classroom	206	8.24												0.00	8.24	NO		
RM 321B - Spec Ed L.D.	classroom	200	8		3										18.42	-10.42	YES		
Rm 321C	classroom	516	20.64		3										18.42	2.22	NO		
Rm 322 - Science	classroom	1052	42.08											7	24.28	17.80	NO		
Rm 324 - Science	classroom	1052	42.08											7	24.28	17.80	NO		
Rm 326 - Science	classroom	1052	42.08											7	24.28	17.80	NO		
Rm 328 - Science	classroom	1052	42.08											6	20.81	21.27	NO		
Rm 330	classroom	730	29.2											6	20.81	8.39	NO		
Rm 332	classroom	734	29.36											7	24.28	5.08	NO		
Rm 334	classroom	630	25.2											6	20.81	4.39	NO		
Rm 336	classroom	749	29.96											7	24.28	5.68	NO		

400 Wing - Second Floor

Boy's - Weight Room - 1	gym	571	22.84						2						8.10	14.74	NO	
Boy's - Toilet Room	toilet room	143	5.72						2						8.10	-2.38	YES	
Boy's - Showers	gym	274	10.96						7						28.34	-17.38	YES	
Boy's - Weight Room - 2	gym	268	10.72						4						16.19	-5.47	YES	
Girls -Shower	gym	1330	53.2						9						36.44	16.76	NO	
Girls - Equiptment Storage	gym	101	4.04						1						4.05	-0.01	YES	
Girls - Exercise Romm	gym	269	10.76						3						12.15	-1.39	YES	
Rm 402	classroom	832	33.28											8	27.75	5.53	NO	
Rm 403	classroom	818	32.72											7	24.28	8.44	NO	
Rm 404	classroom	835	33.4											8	27.75	5.65	NO	
Rm 405	classroom	803	32.12											8	27.75	4.37	NO	
Rm 406	classroom	835	33.4											8	27.75	5.65	NO	
Rm 407	classroom	701	28.04											7	24.28	3.76	NO	
Rm 408	classroom	874	34.96											7	24.28	10.68	NO	
Rm 409	classroom	678	27.12											6	20.81	6.31	NO	
Boys Room	toilet room	224	8.96	1											2.81	6.15	NO	
Girls Room	toilet room	224	8.96	1											2.81	6.15	NO	
Rm 410	classroom	714	28.56											7	24.28	4.28	NO	
Rm 411	classroom	711	28.44											6	20.81	7.63	NO	
Rm 412	classroom	716	28.64											7	24.28	4.36	NO	
Rm 413	classroom	696	27.84											6	20.81	7.03	NO	
Rm 414	classroom	716	28.64											7	24.28	4.36	NO	
Boys Room	toilet room	194	7.76	1											2.81	4.95	NO	
Girls Room	toilet room	194	7.76	1											2.81	4.95	NO	
Rm 415	classroom	784	31.36											7	24.28	7.08	NO	
Rm 416 - English Language	classroom	716	28.64											7	24.28	4.36	NO	
Rm 417	classroom	798	31.92											8	27.75	4.17	NO	
Rm 418	classroom	820	32.8											8	27.75	5.05	NO	
Rm 419	classroom	812	32.48											7	24.28	8.20	NO	
Rm 420	classroom	820	32.8											8	27.75	5.05	NO	
Rm 421	classroom	802	32.08											7	24.28	7.80	NO	
Men's Room	toilet room	220	8.8	1											2.81	5.99	NO	
Women's Room	toilet room	218	8.72	1											2.81	5.91	NO	
Rm 422 - Foreign Language Lab	classroom	820	820											7	24.28	795.72	NO	
Rm 423	classroom	798	31.92											8	27.75	4.17	NO	
Rm 424	classroom	715	28.6											7	24.28	4.32	NO	
Rm 725	classroom	851	34.04											8	27.75	6.29	NO	
Rm 426	classroom	716	28.64											7	24.28	4.36	NO	
Rm 428	classroom	821	32.84											8	27.75	5.09	NO	
Rm 430	classroom	834	33.36											8	27.75	5.61	NO	

Window Type	Width	Hieght	Projection	Venting
B - Hopper	31	14	9	2.81
C - Awning	32	36	13	6.14
D - Hopper - Fixed	0	0	0	0.00
E - Hopper	39	14	11	4.05
F - Fixed	0	0	0	0.00
J - Awning / Hopper	total of both window parts			12.06
L - Hopper	41.5	14	9	3.47
J - Awning (Top)	39	31	18	8.75
J - Hopper (Bottom)	39	14	9	3.31

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