

Worcester Public Schools

Ventilation Assessment & COVID-19 Mitigation Strategies

for

Worcester East Middle School Worcester, MA



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Worcester Public Schools

A. Preface:

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

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

The second part of the report is an evaluation of the natural ventilation. The Building Code requires ventilation of each occupied space and that can be achieved either through mechanical or natural ventilation methods. If the natural ventilation path is chosen, there must be a clear opening(s) in the space that meet or exceed the 4% of the total room square footage. After the field survey of each room / window type was complete, the ventilation information was added to a spread sheet for calculation of the 4% and color-coding. The calculations were also color-coded on a floor plans of the building for a better overall understanding of the existing conditions.

The natural ventilation color-coding (on the spreadsheet and plans) is as follows:

- **Green Spaces**: meets or exceed the code minimum natural ventilation.
- **Yellow Spaces**: does **not** meet the code minimum natural ventilation, but does have operable window to allow some natural ventilation.
- **Red Spaces**: does not meet the code minimum natural ventilation and does not have any operable windows.

It should be reiterated that the second part of this report is only measuring natural ventilation. Therefore, newer buildings or buildings with large amounts of fixed windows may have large amounts of red and/or yellow spaces, but that doesn't mean they are not code compliant, they may be relying on mechanical ventilation. However, for this part of the report, were asked to show a baseline for all schools without mechanical equipment.

B. Building Description:

Worcester East Middle School:

Worcester East Middle School is located in the North Quadrant of Worcester at 420 Grafton Street. The School was built in 1924, houses grades 7-8, has 59 classrooms and the building is 155,392 square feet. The windows are original to the 1924 construction.

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1) Mechanical Ventilation Report

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I. EXECUTIVE SUMMARY

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

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

During, our visual inspection we also took several spot measurements of air quality in various locations throughout the school. Measurements taken were limited to Temperature (°F), Relative Humidity (% RH), CO₂ (carbon dioxide in ppm), CH₂O (formaldehyde in ppm) and Total Volatile Organic Compounds (TVOC in ppm).

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

COVID-19 Control Measures:

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

As of the writing of this report, the City of Worcester Public Schools (WPS) has already begun implementation of several of the measures noted below where possible. For enhanced measures WPS has begun to incorporate Bipolar Ionization (see ECCM-#3) extensively throughout the Worcester East Middle 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 building areas have ventilation limited to operable windows and as such, are not capable of implementing this measure. In some areas there are grilles and vents indicating an old existing vent system however, with no existing drawings to refer to and no control of such systems found on existing control drawings, it is unclear if these are active or could be made active.

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.

Most of the building areas have ventilation limited to operable windows and as such, are not capable of implementing this measure. In some areas there are grilles and vents indicating an old existing vent system however, with no existing drawings to refer to and no control of such systems found on existing control drawings, it is unclear if these are active or could be made active.

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

Most of the building areas have ventilation limited to operable windows and as such, are not capable of implementing this measure. In some areas there are grilles and vents indicating an old existing vent system however, with no existing drawings to refer to and no control of such systems found on existing control drawings, it is unclear if these are active or could be made active.

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

ECCM #1: Portable Room Purifiers - Portable room air purifiers may be used in select areas and rooms to help clean the air within the room. These can be especially helpful where rooms have low outdoor air changes per hour and cannot be supplied with additional outdoor air or where existing systems cannot accommodate improved filtration.

ECCM #2: UV-C Light Sterilization - UV-C lights may be considered for insertion in equipment and ductwork to help neutralize 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 viruses’ ability to infect.

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

Recommendations Summary:

Based on our site inspections, sample air quality readings and review of original drawings we found that a majority of the occupied areas of the Worcester East Middle School do not comply with current ventilation codes. 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 Worcester East Middle School to address the current pandemic condition.

| Space | Exist. O.A. Vent. Systems | Recommendations |
|---------------------------|---------------------------|-----------------------------------|
| General Classrooms | None & Unknown | ECCM - #1 or #3 (*see note below) |
| | | |
| Other Areas | None & Unknown | ECCM - #1 & #3 (*see note below) |
| | | |

**Note: For individual classrooms and other areas noted, ECCM #1 – Portable Air Filtration and/or ECCM #3 – Ionization, are noted as possible options to improve air cleaning and changeover during pandemic conditions. Regardless, we highly recommend outdoor air of some level be provided in all areas having none, even if via windows as there is no substitute for proper ventilation.*

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

II. HVAC VENTILATION ASSESSMENT

A. GENERAL

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

For the Worcester East Middle School, there were no original design drawings to review and as such comments on existing system design intent and capabilities were severely limited. The school facilities were, however, able to give us available HVAC control drawings to ascertain current control configuration. A more detailed and extensive review of old duct routing, where present, and any abandoned equipment would be required to ascertain the viability of its reuse.

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

- Temperature (°F)
- Relative Humidity (% RH)
- CO₂ (carbon dioxide in ppm)
- CH₂O (formaldehyde in ppm)
- Total Volatile Organic Compounds (TVOC in ppm)

These readings were taken at a specific moment in time and may vary during the day based on space occupancy, use and activities as well as the operational state of the HVAC systems. For example, most all spaces surveyed were unoccupied or very lightly occupied and as such most all CO₂ levels were low since space CO₂ is primarily generated by occupants.

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

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

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

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

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

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

B. EVALUATION

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

General Classrooms & Misc. Areas:

A majority of the classrooms in the building are heated with 2-pipe steam radiators. Mechanical ventilation appears to be limited to what can be afforded via operable windows. In some areas there are indications of an old ventilation system however, with no existing drawings and no indication of control of these systems on the control drawings, we suspect they are inactive and abandoned. A more detailed and extensive review of old duct routing, where present, and any abandoned equipment would be required to ascertain the viability of its reuse.

Existing control drawings reflect only control of the boilers and seven (7) zones of radiation. These zones subdivide the building into seven heating zones with temperature monitoring of thirty-two spaces.

For a standard classroom, current code would require 10 CFM per person of outside air plus 0.12 CFM per SF. For a system with a presumed zone air distribution effectiveness of 1.0, a room size of 800 SF with 26 occupants (25 students + 1 teacher) would require 356 CFM of outdoor air (445 CFM if ZDE = 0.8).

Bathroom and local exhaust requirements appear to be supported by some type of exhaust system of unknown capacity.

Science & Art Rooms:

There current science rooms and art rooms appear to be ventilated no different than most other classrooms with no signs of active supply air ventilation. However, at least one basement level art/trade room had a thru wall exhaust fan and the upper-level science room had an old fume hood exhaust hood and a new storage room exhaust.

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 building ventilation levels for these rooms is non-compliant, especially if the spaces are actual used as art and science rooms with gas and/or chemical use. If the rooms are not used in this way than the lower typical classroom ventilation levels may apply.

Controls:

Controls in the building appear to be extremely limited. Existing control drawings reflect only control of the boilers and seven (7) zones of radiation. These zones subdivide the building into seven heating zones with temperature monitoring of thirty-two spaces. The energy management system (EMS) is currently supported by Automated Building Systems, Inc (ABS).

The operating schedule for the heating zones is based on the school's occupancy schedule. The schedule is adjustable via the front-end computer workstation.

C. IAQ & Ventilation Summary

IAQ Summary:

During our inspection we obtained spot measurements of air quality in various locations throughout the school. Measurements taken were limited to:

- Temperature (°F)
- Relative Humidity (% RH)
- CO₂ (carbon dioxide in ppm)
- CH₂O (formaldehyde in ppm)
- Total Volatile Organic Compounds (TVOC in ppm)

The readings were taken at a specific moment in time and may vary during the day based on space occupancy, use and activities as well as the operational state of the HVAC systems. For example, most all spaces surveyed were unoccupied or very lightly occupied and as such most all CO₂ levels were low since space CO₂ is primarily generated by occupants.

In addition, we noted some elevated TVOC levels and/or formaldehyde levels in areas which would not generally be expected to have such elevated levels. Although TVOC's (which includes formaldehyde) may come from varied sources such as cleaners, air fresheners and such, formaldehyde levels are often from off-gassing of furnishings or building materials. It is important to note that elevated levels of TVOC's may have been partially caused by recent enhanced cleaning measures or due to ventilation systems that were not in full operation at the time.

Measurements taken included space humidity. Humidity levels has been found to play a role in the controlling the spread of COVID-19. ASHRAE recommends winter humidity levels be kept between 40% to 50% and summer humidity levels between 50% and 60% with a summer target of 50%. Maintaining humidity levels within the above ranges has been found to limit the growth and transmission of certain bacteria and viruses as well as supports respiratory function. The below chart is taken from the 2020 ASHRAE Handbook – HVAC Systems and Equipment and reflects the impact of space humidity on the increase or decrease of effect on various space contaminants. This chart only reflects increase or decrease of effect from humidity and does not intend to imply that there is zero growth or impact of a certain contaminant when the sloped bar graph zero's out.

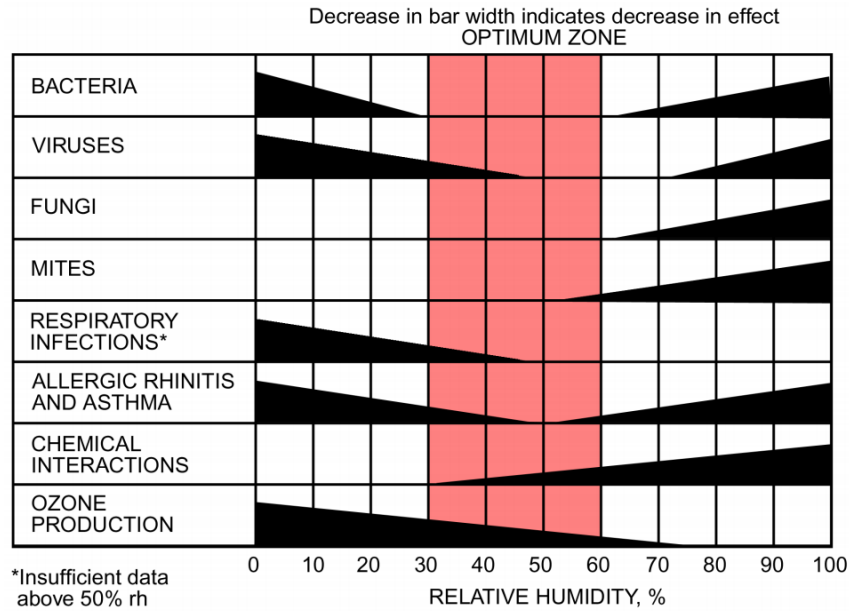


Fig. 1 Optimum Humidity Range for Human Comfort and Health
 (Adapted from Sterling et al. 1985)

The Worcester East Middle School HVAC systems have no active humidity control. Space dehumidification is limited only to those areas which have air conditioning cooling. However, this dehumidification is not actively controlled by a humidity setpoint. Moisture removal only occurs when these systems are operating in the cooling mode. As such, space humidity may climb above 60% during periods when low thermal loads require less cooling (i.e., 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 Worcester East Middle School often have poor vapor barrier the varying wall and window construction and thermal characteristics may limit the ability for active humidification. Adding humidity in the wintertime without consideration of the building construction could result in moisture condensation on windows and within wall assemblies which may create a damaging and unhealthy condition for the building and its occupants. Review of the building envelope should take place prior to consideration of the addition of any humidification system. As such, our recommendations contained with this report exclude active humidification control until such time as the envelope can be reviewed.

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

The document entitled “5-Step Guide to Checking Ventilation Rates in Classrooms” from the Harvard T.H. Chan School of Public Health recommends a target outdoor air exchange rate

during these pandemic conditions. The document identifies 5 air changes per hour (ACH) and above as “excellent” down to a 3 ACH being considered “bare minimum”. Many of the general classrooms in the Worcester East Middle School have an outdoor air exchange rate presumed to be well below 3. When the outdoor air exchange rate is lower than the target 5 ACH, the document recommends the following strategies:

1. Increase outdoor air (see CCM #2)
2. Use MERV 13 filters (or greater) on recirculated air (see CCM #3)
3. Add portable air cleaners with HEPA filters to the classroom (see ECCM #1)

It should be made clear however, that a room that has less than what this document considers the bare minimum outdoor air exchange rate may meet or exceed the most current ventilation standards dependent on the space occupancy and therefore may not be considered under ventilated by code standards. The 5 ACH or greater recommendation is meant to address the pandemic conditions being experienced as this level of ACH would equate to nearly 100% outside air requirement for a conventional mixed air cooling & heating system.

The following tables describe areas and systems where the above measures as well as others presented in this report may be applied.

| Worcester East Middle School IAQ Sampling Summary | | | | | | | | | | | |
|---|-------------|------------------|----------|-------------|-------------|-------------------|----------------|----------------------|------------------------------|---------------------------|-------|
| Space Tested | Temp. °F | Humidity % RH | CO2 % | TVOC ppm | HCHO ppm | Room Area SqFt | Room Ht. Ft | Volume Cubic Feet | Original Design OA CFM | Original OA Air ACH | Notes |
| Basement | | | | | | | | | | | |
| Cafeteria | 69.9 | 30.2 | 469 | 1.36 | 0.18 | 3225 | 8.25 | 26606 | na | na | |
| Kitchen | 70.5 | 28.5 | 453 | 1.38 | 0.16 | 1249 | 8.25 | 10304 | na | na | |
| Art Room B6 | 73.5 | 29.7 | 471 | 1.35 | 0.17 | 1315 | 9.83 | 12926 | na | na | |
| Room B4 | 79.1 | 32.1 | 494 | 1.39 | 0.18 | 1637 | 9.92 | 16239 | na | na | |
| Gymnasium B27 | 70.9 | 40.5 | 475 | 1.36 | 0.18 | 6908 | 21.58 | 149075 | na | na | |
| Dance Studio (old girls shower room) | 71.9 | 38.8 | 477 | 1.36 | 0.19 | 2072 | 10 | 20720 | na | na | |
| Weight Room (old boys locker room) | 71.1 | 32.5 | 476 | 1.36 | 0.16 | 1490 | 10 | 14900 | na | na | |
| Theater Room B18 | 74 | 31.5 | 486 | 1.48 | 0.14 | 731 | 10.83 | 7917 | na | na | |
| ESL B1 | 78.1 | 32.2 | 485 | 1.9 | 0.18 | 384 | 9.92 | 3809 | na | na | |
| First Floor | | | | | | | | | | | |
| Library 114/115 | 73.6 | 28 | 511 | 1.38 | 0.19 | 1979 | 11.92 | 23590 | na | na | |
| ESL Room 116 | 72.7 | 27.3 | 473 | 1.35 | 0.2 | 739 | 12 | 8868 | na | na | |
| Classroom 117 | 73.1 | 29.4 | 475 | 1.36 | 0.18 | 730 | 12 | 8760 | na | na | |
| Nurse Reception 119 | 75.3 | 28.2 | 512 | 1.78 | 0.34 | 198 | 8.5 | 1683 | na | na | |
| Sick Room 119B | 76.9 | 26.6 | 498 | 1.7 | 0.32 | 130 | 12 | 1560 | na | na | |
| ESL 120 | 77.7 | 25 | 478 | 1.43 | 0.21 | 730 | 11 | 8030 | na | na | |
| Counciler (old asst princ) | 77.3 | 28.5 | 535 | 1.58 | 0.24 | 185 | 8 | 1480 | na | na | |
| Main Office | 78.4 | 29.1 | 552 | 1.77 | 0.3 | 218 | 9.75 | 2126 | na | na | |
| Assistant Principal (old gear up office) | 77.1 | 28.5 | 533 | 1.63 | 0.26 | 180 | 8 | 1440 | na | na | |
| Principal Office | 77.9 | 27.5 | 529 | 1.65 | 0.27 | 324 | 8.58 | 2780 | na | na | |
| Conference Room | 76.7 | 26 | 509 | 1.49 | 0.19 | 283 | 9.66 | 2734 | na | na | |
| Supply Room 101 | 76 | 24.4 | 465 | 1.42 | 0.2 | 350 | 9.66 | 3381 | na | na | |
| Office 101 (old guidance room) | 77.6 | 28.6 | 488 | 1.37 | 0.2 | 278 | 9.5 | 2641 | na | na | |
| Science Room 108 | 69 | 25.7 | 458 | 1.31 | 0.16 | 735 | 12 | 8820 | na | na | |
| Room 105 | 77.9 | 26.1 | 463 | 1.32 | 0.16 | 718 | 12 | 8616 | na | na | |
| Second Floor | | | | | | | | | | | |
| Room 210 | 76 | 23.1 | 502 | 1.42 | 0.16 | 453 | 11 | 4983 | na | na | |
| Room 209 | 76.1 | 23.8 | 489 | 1.42 | 0.18 | 972 | 11 | 10692 | na | na | |
| Room 206 | 79.4 | 25.6 | 482 | 1.46 | 0.19 | 768 | 11 | 8448 | na | na | |
| Room 216 | 83.2 | 23.5 | 478 | 1.41 | 0.19 | 702 | 11 | 7722 | na | na | |
| Guidance Room (old art stor) | 83.7 | 24.4 | 491 | 1.44 | 0.19 | 169 | 9.5 | 1606 | na | na | |
| Auditorium | 79.6 | 28.4 | 490 | 1.44 | 0.16 | 3655 | 33.17 | 121236 | na | na | |
| Big Conference (old music 200 A&B) | 80.9 | 29.1 | 479 | 1.41 | 0.19 | 1258 | 9.58 | 12052 | na | na | |
| Assistant Principal | 78.1 | 22.3 | 463 | 1.46 | 0.16 | 113 | 9.42 | 1064 | na | na | |
| Third Floor | | | | | | | | | | | |
| Room 312 | 73.1 | 31.3 | 481 | 1.53 | 0.17 | 751 | 11.92 | 8952 | na | na | |
| Room 316 | 81 | 28.4 | 505 | 1.49 | 0.18 | 744 | 11 | 8184 | na | na | |
| Room 311 | 71.1 | 37.2 | 494 | 1.53 | 0.18 | 1579 | 9.58 | 15127 | na | na | |
| Assistant Principal | 82.1 | 25 | 541 | 1.5 | 0.18 | 251 | 10 | 2510 | na | na | |
| Faculty Room | 77.1 | 26 | 481 | 1.57 | 0.17 | 251 | 10 | 2510 | na | na | |
| Room 301 | 78.9 | 26.7 | 482 | 1.52 | 0.18 | 901 | 11 | 9911 | na | na | |
| Room 307 | 75.6 | 28.9 | 475 | 1.56 | 0.15 | 737 | 11 | 8107 | na | na | |
| Room 306 | 77.2 | 31.2 | 476 | 1.57 | 0.18 | 462 | 11 | 5082 | na | na | |
| Science Room 305 | 78.9 | 27.6 | 483 | 1.58 | 0.14 | 982 | 11 | 10802 | na | na | |

Note: As noted previously, the TVOC readings tended to drift up during the study, possibly due to a calibration issue, as such, the readings in this report were only used to identify areas where possible ventilation issues may exist and/or to identify areas where a source contaminant may be causing elevated levels.

Ventilation System Summary & Recommendations:

The following table is based on original design drawings and reflect most of the systems which provide ventilation air to the building. The units ID tag, area served, ventilation data and filter efficiencies are listed. The table also reflects possible COVID Control Measures (CCM) and Enhanced COVID Control Measures (ECCM) described later in this report which may apply to such systems to improve performance either during pandemic conditions and/or post pandemic conditions.

| Worcester East Middle 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 |
| Misc. | Entire Bldg. | N/A | N/A | N/A | unknown | unknown | N/A | N/A | #1, #3 | a, 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. We highly recommend outdoor air of some level be provided in areas having none, even if via windows as there is no substitute for proper ventilation regardless of other measures employed. Science and art rooms should be supplied with added ventilation to comply with current code.

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 East Middle School surveyed are outline herein. Refer to the Ventilation System Summary Table for applicable CCM recommendations.

It is imperative that all systems be maintained and checked to confirm proper operation in line with their original design, adjusted where applicable, as described herein. In addition, a Testing and Balancing company should be enlisted to adjust and confirm all systems are properly achieving their design outdoor air, supply air and exhaust air levels.

For Worcester East Middle School, a more detailed and extensive review of old duct routing, where present, and any abandoned equipment would be required to ascertain the viability of its reuse.

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, or lack thereof, supporting the Worcester East Middle School are not capable of implementing this measure.

CCM #2 – Increased Ventilation

Increase outdoor air ventilation for improved space dilution where systems allow. This would entail increasing the minimum outdoor air damper positions on all mixed air style systems within the limits of the equipment capacity and overriding any demand ventilation reset schemes (i.e., CO2 reset). A control sequence would need to be implemented for the respective air handlers which would limit the outdoor air volume to the unit's respective capability such that proper control of the discharge air can be maintained as well as freeze protection of coils. In addition, sequence would need to include limitation based on boiler

plant and cooling system capabilities and summertime moisture limitations. For buildings which have anti-freeze in water-based heating and/or cooling systems concern of unitary coil freeze up is reduced.

Most of the HVAC systems, or lack thereof, supporting the Worcester East Middle School are not capable of implementing this measure.

CCM #3 – Improved Filtration

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

Most of the HVAC systems, or lack thereof, supporting the Worcester East Middle School are not capable of implementing this measure.

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 for applicable recommendations.

ECCM #1: Portable Room Purifiers

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

ECCM #2: UV-C Light Sterilization

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

ECCM #3: Bipolar Ionization

Air ionizers are meant to be installed in the supply air duct or plenum downstream of fans and filters. They are also offered as portable units for room application. In Worcester East Middle Schools case they could be installed in the UV system as well as portable units could be used. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Worcester East Middle School to address the current pandemic condition.

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

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

technology being that there are not extensive 3rd party studies and reviews of its capability in this regard.

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

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

2) Natural Ventilation Summary

Worcester East Middle 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 sq ft | PASS? | Additional Notes | | | |
|---|-----------|---------------------|----------------|---------------------------|---|---|----|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|----------------------|--|-------|------------------|--------|-----|------------------|
| | | | | A | B | C | D | AC | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | | | | | X | Y | |
| Basement Floor | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B01 - Prep Room | classroom | 384 | 15.36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 15.36 | NO | |
| B02 - Dark Room | classroom | 183 | 6.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 6.52 | NO | |
| B03 - Supply Closet | storage | 93 | 3.72 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 3.72 | NO | |
| B04 - Technology Education | classroom | 694 | 27.76 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 37.10 | -9.34 | YES | |
| B05 - Technical Education | classroom | 728 | 29.12 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | 37.10 | -7.98 | YES | |
| B06 - Technical Drawing | classroom | 1252 | 50.08 | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | 45.67 | 4.41 | NO | |
| B07 - Wood Technology | classroom | 1637 | 65.48 | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | 57.08 | 8.40 | NO | |
| B08 - Supply Room | storage | 95 | 3.80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 3.80 | NO | |
| B09 - Storage | storage | 65 | 2.60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 2.60 | NO | |
| B10 - Wood Storage | support | 736 | 29.44 | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | 22.83 | 6.61 | NO | |
| B11 - Technology | classroom | 1115 | 52.60 | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | 45.67 | 6.93 | NO | |
| B12 - Storage | storage | 104 | 4.16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.16 | NO | |
| B13 - Storage | storage | 82 | 3.28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 3.28 | NO | |
| B14 - Teacher's Dining Room | support | 473 | 18.92 | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | 22.83 | -3.91 | YES | |
| B15 - Kitchen | support | 235 | 9.40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 9.40 | NO | |
| B16 - Kitchen | kitchen | 1249 | 49.96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 19.03 | 30.93 | NO | |
| B17 - Cafeteria | office | 58 | 2.32 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | 0.00 | 2.32 | NO | |
| B18 - Food Storage | storage | 366 | 14.64 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 14.64 | NO | |
| B19 - Refrigerator | support | 67 | 2.68 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 2.68 | NO | |
| B20 - Freezer | support | 131 | 5.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 5.24 | NO | |
| B21 - Kitchen Toilet | toilet | 113 | 4.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.52 | NO | |
| B22 - Breakroom | support | 255 | 10.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 10.20 | NO | |
| B23 - Cafeteria | cafeteria | 3225 | 129 | | | | 12 | | | 1 | | | | | | | | | | | | | | | | | | | | | 158.89 | -29.89 | YES | |
| B24 - Conference | support | 203 | 8.12 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | 0.00 | 8.12 | NO | |
| B25 - Spec Edu | classroom | 799 | 31.96 | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | 44.24 | -12.28 | YES | |
| B26 - Guidance Storage | storage | 420 | 16.80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 16.80 | NO | |
| B27 - Spec Edu | classroom | 731 | 29.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 31.17 | -1.93 | YES | |
| B28 - Spec Edu / ED | classroom | 773 | 30.92 | | | | 3 | | | | | | | | | | | | | | | | 1 | | | | | | | | 8.57 | 22.35 | NO | |
| B29 - Tag | office | 123 | 4.92 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.92 | NO | |
| B30 - AD Office | office | 117 | 4.68 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.68 | NO | |
| B31 - AD Office - Closet | storage | 38 | 1.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 1.52 | NO | |
| B32 - AD Office | office | 118 | 4.72 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.72 | NO | |
| B33 - Time Out / Restriction Room | classroom | 305 | 12.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 12.20 | NO | |
| B34 - Gymnasium | gym | 6907 | 276.28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 276.28 | NO | |
| B35 - Gymnasium Assistant | support | 223 | 8.92 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 8.92 | NO | |
| B36 - Gym Storage | storage | 192 | 7.68 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 7.68 | NO | |
| B37 - Instructor's Office - A | office | 158 | 6.32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 6.32 | NO | |
| B38 - Instructor's Office - A - Storage | storage | 106 | 4.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.24 | NO | |
| B39 - Instructor's Office - A - Toilet | toilet | 106 | 4.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 4.24 | NO | |
| B40 - Instructor's Office - A | office | 172 | 6.88 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 6.88 | NO | |
| B41 - Instructor's Office - B - Closet | storage | 10 | 0.40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 0.40 | NO | |
| B42 - Boy's Locker Room | gym | 349 | 13.96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 13.96 | NO | |
| B43 - Boy's Toilet | toilet | 154 | 6.16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 6.16 | NO | |
| B44 - Boy's Locker | gym | 305 | 12.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 12.20 | NO | |
| B45 - Boy's Exercise Room | gym | 681 | 27.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 27.24 | NO | |
| B46 - Boy's Trainer Room | support | 261 | 10.44 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 10.44 | NO | |
| B47 - Boy's Trainer Storage | storage | 260 | 10.40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 10.40 | NO | |
| B48 - Gym Storage | storage | 273 | 10.92 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 10.92 | NO | |
| B49 - Boy's Locker Room (adj) | gym | 188 | 7.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 7.52 | NO | |
| B50 - Boy's Locker Room | gym | 475 | 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 19.00 | NO | |
| B51 - Boy's Toilet Room (Corridor) | toilet | 86 | 3.44 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 3.44 | NO | |
| B52 - Girl's Locker Room (Corridor) | toilet | 77 | 3.08 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 3.08 | NO | |
| B53 - Girl's Locker Room | gym | 2072 | 82.88 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 82.88 | NO | |
| B54 - Girl's Locker Room | gym | 148 | 5.92 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 5.92 | NO | |
| B55 - A/V Equipment Storage | storage | 188 | 7.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 7.52 | NO | |
| B56 - Girl's Toilet | toilet | 169 | 6.76 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 6.76 | NO | |
| B57 - Boy's Toilet (restroom) | toilet | 63 | 2.52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 2.52 | NO | |
| B58 - South Light Court | support | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 0.00 | NO | |
| B59 - In-School Suspension | classroom | 434 | 16.96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 16.96 | NO | |
| First Floor | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F01 - Supply Room | storage | 350 | 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 14.00 | NO | Room now divided |
| F02 - Closet | storage | 28 | 1.12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 1.12 | NO | |
| F03 - Cust Supply | storage | 44 | 1.76 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 1.76 | NO | |
| F04 - Guidance Room | support | 277 | 11.08 | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | 26.69 | -16.41 | YES | |
| F05 - Guidance Counselor | office | 56 | 2.24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.00 | 2.24 | NO | |
| F06 - Guidance Counselor | office | 53 | 2.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

