

Worcester Public Schools

Ventilation Assessment & COVID-19 Mitigation Strategies

for

Transportation Offices at 60 Fremont Street Worcester, MA



January 31, 2021

Prepared by:

**Nault Architects Inc
71 Hope Ave
Worcester, MA 10603**

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

&

Worcester Public Schools

A. Preface:

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

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

The second part of the report is an evaluation of the natural ventilation. The Building Code requires ventilation of each occupied space and that can be achieved either through mechanical 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:

Transportation Offices:

The Transportation Offices, also know at the "Bus Depot" is located ed in the South Quadrant of Worcester at 60 Fremont Street. The portion of the building that is occupied by WPS transportation staff is 8,800 square feet.

C. Table of Contents:

| | |
|--|----|
| 1) Mechanical Ventilation Report | 16 |
| 2) Natural Ventilation Summary..... | 3 |

1) Mechanical Ventilation Report

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY..... 2

II. HVAC VENTILATION ASSESSMENT..... 5

 A. General..... 5

 B. Evaluation..... 7

 C. IAQ & Ventilation Summary..... 11

III. COVID-19 HVAC MITIGATION MEASURES..... 15

 A. HVAC COVID-19 Control Measures..... 15

 B. Enhanced HVAC COVID-19 Control Measures 17

I. EXECUTIVE SUMMARY

This report briefly describes the existing ventilation systems at the Transportation Offices 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. Even though this building is not used for classroom space, the Harvard guidelines were applied as a reference. 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 Transportation Offices 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.

Only the system supporting the 2nd floor offices is capable of implementing this measure. The ground floor area system is not currently capable of supporting this measure as the system introduces no outdoor air.

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.

Only the system supporting the 2nd floor offices may be capable of implementing this measure. The ground floor area system is not currently capable of supporting this measure as the system introduces no outdoor air.

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

The RTU unit serving the second-floor office is of an age where it would not be capable of supporting filtration in excess of MERV 8. The ground floor fan coil unit serving the break room currently has MERV 8 filters however, it appears the unit may be modified with external duct mounted oversized filter racks to achieve MERV 13 filtration subject to unit testing. All other systems serving the current areas cannot support increased filtration levels. Increased filter efficiency can lead to faster filter loading and a potential reduction in ventilation air for systems not designed to support this filtration level.

Systems retrofitted with MERV 13 must be tested and adjusted to accommodate the pressure drop associated with the increased filter efficiency. In addition, more frequent filter changes would be expected to limit reduction in ventilation air as the filters load.

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

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

ECCM #2: UV-C Light Sterilization - UV-C lights may be considered for insertion in equipment and ductwork to help neutralize viruses as it is exposed to the light.

ECCM #3: Bipolar Ionization - Air ionizers may be installed in air handling systems or portable units installed in rooms to improve indoor air quality. These systems cause particles and airborne contaminants to bind together thereby increasing their size, so they tend to either drop out of the breathing zone or be better removed by air filtration. Recent studies have also shown Bipolar Ionization may inhibit the COVID-19 virus's ability to infect.

WPS has begun to incorporate Bipolar Ionization extensively throughout the Transportation Offices to address the current pandemic condition.

Recommendations Summary:

Based on our site inspections, sample air quality readings we found that the 2nd floor areas of the Transportation Offices may comply with current ventilation codes pending testing however most other areas do not. 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 Transportation Offices to address the current pandemic condition.

| Space | Exist. O.A. Vent. Systems | Recommendations |
|--|---------------------------|--|
| 1st Floor Offices | Fan Coil | ECCM - #1 & #3 (*see note below) |
| 1st Floor Break Room | Fan Coil - Ducted | CCM - #3 (with duct modifications) ECCM - #1 & #3 (*see note below) |
| 2nd Floor Offices | Packaged Rooftop Unit | CCM - #1 & #2 ECCM - #3 |

**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 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.

Unfortunately, for the transportation offices, there were no existing HVAC plans nor control drawings available for review so as to verify system operation as well as to compare them to current ventilation codes and standards. As such, 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 are based on current code. 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.

There are no existing HVAC design drawings or equipment schedules available for review of original design intent. As such, we cannot comment on the existing ventilation levels except for where there are apparently no such systems in place. If design drawings of the 2nd floor system cannot be found, we suggest field airflow testing as well as further review with the control vendor to establish ventilation levels.

Ground Floor Offices & Breakroom:

The ground floor office spaces are supported by a ductless split fan coils system. These systems are not capable to improved filtration and operate with a washable filter with a MERV rating below 8. A nearby breakroom is supported by a ducted split fan coil system. Outdoor air ventilation for these areas is limited to what can be afforded via operable windows.

The break room unit is fitted with MERV 8 filters. Although the unit filter rack cannot support a higher MERV rating, it would appear the unit is of a style that may be able to support higher filtration up to MERV 13 with the addition of external filter racks and associated duct modifications.

For an office space, current code would require 5 CFM per person of outside air plus 0.06 CFM per SF. For an average 550 SF office on this level, presuming 3 people per office, the room would require 48 CFM of outdoor air (assumes ZDE of 1.0). As none of the areas, have any outdoor air ventilation, they do not comply with current mechanical ventilation codes.

For the breakroom, current code would require 7.5 CFM per person of outside air plus 0.18 CFM per SF. The 1,984 SF breakroom with an estimated occupant load of 50 would require an outdoor air rate of 733 CFM (assumes ZDE of 1.0). As this area, has no outdoor air ventilation, it does not comply with current mechanical ventilation codes.

Second Floor Offices:

The second-floor office areas are supported by a packaged rooftop HVAC unit. The unit are fitted with a mixing box, filter section, electric heat section, DX cooling section and supply fan. The unit was retrofitted with an external variable speed drive (VSD) for presumed speed control of the fan for operation as a variable air volume (VAV) system. We were not able to access the VAV terminals during our inspection to confirm type or control.

As this is a mixed air system, the amount of outdoor air delivered to each space varies based on the amount of primary air being introduced through the respective VAV terminal. When the primary air reduces which, it does for a typical VAV terminal, the percentage of outdoor air would drop thereby potentially under ventilating the space.

Current mechanical code would require VAV systems such as this to have the ability to maintain the outdoor air volume constant across the unit's variable supply airflow operation. For example, if the unit provided 20% outside air at full airflow, if the units total airflow dropped to 50%, the outdoor airflow quantity should remain constant thereby making the outdoor air percentage 40%. This would help maintain proper outdoor airflow to the various spaces as the VAV terminals vary. Although control drawings would need to be located and reviewed, we suspect the existing unit does not operate in this fashion and does not monitor the amount of outdoor air the unit is introducing.

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

For an office space, current code would require 5 CFM per person of outside air plus 0.06 CFM per SF. For an average single person office of 150 SF this would require 14 CFM of outdoor air. For the training room the density of occupants per SF is much higher than for standard offices space resulting in 37 occupants for this size space and a required outdoor air rate of 222 CFM (assumes ZDE of 1.0).

Testing of the system would be required to confirm the volume of outdoor air being provided to the spaces with special attention to VAV airflow control to verify current compliance. The unit is currently fitted with MERV 8 filters however, it is very old at more than 30 years and as such we suspect cannot support a higher filtration level.

Controls:

We were unable to obtain existing control drawings for these systems. Review of these drawings with the control vendor would be required to verify current system operation.

C. IAQ & Ventilation Summary

IAQ Summary:

During our inspection we obtained spot measurements of air quality in various locations throughout the WPS areas of the building. 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.

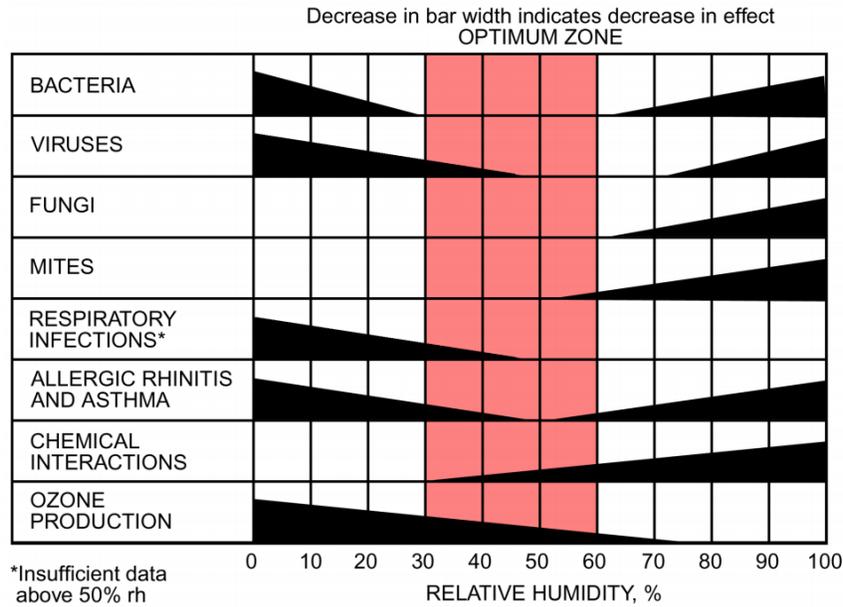


Fig. 1 Optimum Humidity Range for Human Comfort and Health
 (Adapted from Sterling et al. 1985)

The transportation offices 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 Transportation Offices often have a poor vapor barrier the varying wall and window construction and thermal characteristics which 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”. Although there are no classrooms in the areas surveyed, the design outdoor air exchange rate is presumed to be well below 3 as it is limited to infiltration and operable windows for the ground floor and an unknown varying level through the RTU on the second floor. When the outdoor air exchange rate is lower than the target 5 ACH, the document recommends the following strategies:

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

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

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

| Transportation Offices IAQ Sampling Summary | | | | | | | | | | | |
|--|-------------|------------------|----------|-------------|-------------|-------------------|----------------|----------------------|------------------------------|---------------------------|-------|
| Space Tested | Temp. °F | Humidity % RH | CO2 % | TVOC ppm | HCHO ppm | Room Area SqFt | Room Ht. Ft | Volume Cubic Feet | Existing Design OA CFM | Existing OA Air ACH | Notes |
| 1st Floor | | | | | | | | | | | |
| Dispatch/Operations Manager | 67.4 | 22.4 | 890 | 4.52 | 0.6 | 576 | 15.41 | 8876 | 0 | 0 | |
| Fleet Manager/Parts Room | 66.6 | 21.9 | 868 | 4.91 | 0.65 | 528 | 15.41 | 8136 | 0 | 0 | |
| Breakroom | 68.8 | 25.2 | 855 | 3.41 | 0.33 | 1984 | 15.41 | 30573 | 0 | 0 | |
| 2nd Floor | | | | | | | | | | | |
| Office 1 | 66.2 | 22 | 578 | 2.91 | 0.22 | 202 | 8.58 | 1733 | N/A | N/A | |
| Office 2 | 66.6 | 20.7 | 513 | 2.91 | 0.24 | 139 | 8.91 | 1238 | N/A | N/A | |
| Training Room | 67.2 | 20.4 | 494 | 2.93 | 0.25 | 742 | 8.83 | 6552 | N/A | N/A | |

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.

| 60 Fremont St Transportation Office Ventilation System Summary | | | | | | | | | | |
|--|------------------------|-------------------|-----------------|---------------|---|---------------------------|--------------------------|----------------|-----------------|---------|
| Unit ID | Area Served | Exist. Supply CFM | Exist. O.A. CFM | Exist. O.A. % | Exist. Filter Qty & Size | Exist. Filter MERV Rating | Exist. Filter Vel. (FPM) | Proposed CCM # | Proposed ECCM # | Notes |
| RTU - # | 2nd Floor Offices | 8000 est. | N/A | N/A | (6) 20x20x2 (1) 16x20x1 (1) 20x20x1 | 8 | N/A | #1, #2 | #1, #3 | a, c |
| FC - # | Ground Floor Breakroom | N/A | 0 | 0 | (1) 16x20x1 (1) 20x20x1 | 8 | N/A | #3 (see d) | #1, #3 | a, b, d |
| FC - # | Ground Floor Offices | N/A | 0 | 0 | N/A | less than 8 | N/A | | #1, #3 | a, b |

Ventilation System Summary Notes:

- a. For individual rooms 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 mechanical ventilation of outdoor air of some level be provided, even if via windows, as there is no substitute for proper ventilation regardless of other measures employed.
- c. To improve the ventilation effectiveness and outdoor airflow control of the admin. office VAV system we would recommend airflow stations be added to the outdoor airflow and exhaust airflow of the RTU unit along with associated control improvements.
- d. Pending testing, MERV 13 filter racks could be added to the system (duct modifications and external filters required).

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 Transportation Offices 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.

Only the system supporting the 2nd floor offices may be capable of implementing this measure. The ground floor area system is not currently capable of supporting this measure as the system introduces no outdoor air.

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.

Only the system supporting the 2nd floor offices may be capable of implementing this measure. The ground floor area system is not currently capable of supporting this measure as the system introduces no outdoor air.

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

CCM #3 – Improved Filtration

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

The RTU unit serving the second-floor office is of an age where it would not bot capable of supporting filtration in excess of MERV 8. The ground floor fan coil unit serving the break room currently has MERV 8 filters however, it appears the unit may be able to be modified with external duct mounted oversized filter racks to achieve MERV 13 filtration subject to unit testing. All other systems serving the current areas cannot support increased filtration levels. 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.

Prior to implementation of higher filtration levels in excess of MERV 8, existing equipment capabilities must be reviewed to verify it can support the added pressure drop imposed by MERV-13 filtration. Testing and Balancing to confirm current airflow, pressure drops, and fan motor power coupled with manufacturer. published data would be required to confirm the unit’s capability for improved filtration.

B. ENHANCED HVAC COVID-19 CONTROL MEASURES

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

ECCM #1: Portable Room Purifiers

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

ECCM #2: UV-C Light Sterilization

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

ECCM #3: Bi-Polar Ionization

Air ionizers are meant to be installed in the supply air duct or plenum downstream of fans and filters. They are also offered as portable units for room application. In the Transportation Offices case they could be installed in the supply air duct of the second-floor air handling systems and in the breakroom system with portable units being used elsewhere. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Transportation Offices 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

Bus Depot - 60 Freemont St

| 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 |
|----------------------------------|-----------|---------------------|----------------|---------------------------|--------|--------|--------|----------------------|---|-------|------------------|
| | | | | DBL HUNG | A 9.75 | B 2.69 | HOPPER | | | | |
| Ground Level | | | | | | | | | | | |
| Control / Dispatch Office | office | 317 | 12.68 | | 6 | | | 58.50 | -45.82 | YES | |
| Operations Manger Office | office | 259 | 10.36 | | 2 | | | 19.50 | -9.14 | YES | |
| Fleet Manager Office / Inventory | office | 528 | 21.12 | | 4 | | | 39.00 | -17.88 | YES | |
| Vehicle Maintenance Bay | garage | 1067 | 42.68 | | | | | 0.00 | 42.68 | NO | |
| Remote Dispatch Office | office | 300 | 12 | | | | | 0.00 | 12.00 | NO | |
| Break Room | common | 1984 | 79.36 | | 10 | | | 97.50 | -18.14 | YES | |
| Women's Room | toilet | 187 | 7.48 | | 3 | | | 29.25 | -21.77 | YES | |
| Men's Room | toilet | 145 | 5.8 | | | | | 0.00 | 5.80 | NO | |
| Second Level | | | | | | | | | | | |
| Storage Room | storage | 467 | 18.68 | | | | | 0.00 | 18.68 | NO | |
| Men's Room | toilet | 116 | 4.64 | | | | | 0.00 | 4.64 | NO | |
| Women's Room | toilet | 116 | 4.64 | | | | | 0.00 | 4.64 | NO | |
| Storage Room | storage | 176 | 7.04 | | | | | 0.00 | 7.04 | NO | |
| Office | office | 180 | 7.2 | | | | | 0.00 | 7.20 | NO | |
| Office | office | 177 | 7.08 | | | | | 0.00 | 7.08 | NO | |
| Office | office | 177 | 7.08 | | | | | 0.00 | 7.08 | NO | |
| Office | office | 177 | 7.08 | | | | | 0.00 | 7.08 | NO | |
| Saftey Office | office | 150 | 6 | | | 2 | | 5.39 | 0.61 | NO | |
| Office | office | 139 | 5.56 | | | 1 | | 2.69 | 2.87 | NO | |
| Office | office | 139 | 5.56 | | | 1 | | 2.69 | 2.87 | NO | |
| Office | office | 139 | 5.56 | | | 1 | | 2.69 | 2.87 | NO | |
| Office | office | 202 | 8.08 | | | 1 | | 2.69 | 5.39 | NO | |
| Office | office | 287 | 11.48 | | | | | 0.00 | 11.48 | NO | |
| Training Room | common | 742 | 29.68 | | | | | 0.00 | 29.68 | NO | |
| Office | office | 315 | 12.6 | | | | | 0.00 | 12.60 | NO | |
| Office | office | 315 | 12.6 | | | | | 0.00 | 12.60 | NO | |

| Window Type | Width | Hieght | Projection | Venting |
|-----------------|-------|--------|------------|---------|
| A - Double Hung | 39 | 36 | 0 | 9.75 |
| B - Hopper | 55 | 15.5 | 5.5 | 2.69 |

| 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) |