

Worcester Public Schools

Ventilation Assessment & COVID-19 Mitigation Strategies

for

Thorndyke Road 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:

Thorndyke Road School:

The Thorndyke Road School is located in the Burncoat Quadrant of Worcester at 30 Thorndyke Road. The school was built in 1927, houses grades PK-06, has 9 classrooms and the building is 43,425 square feet. The windows in this building were replaced in 2018.

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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 Thorndyke Road 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 Thorndyke Road 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.

The building areas are supported by either classroom unit ventilators or a central ventilation system running in the basement level and serving rooms via vertical shafts. The condition of this ventilation system is unknown however, there is a fan connected to this system which appears to be in operational order. As such, the building may be capable of this measure pending operational testing, balancing and control verification.

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.

The building areas are supported by either classroom unit ventilators or a central ventilation system running in the basement level and serving rooms via vertical shafts. The condition of this ventilation system is unknown however, there is a fan connected to this system which appears to be in operational order. As such, the building may be capable of this measure pending operational testing, balancing and control verification.

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

We were unable to locate air filters on the central ventilation system. However, if it is to remain in use filters should be added and the fan capability tested to confirm maximum filtration level. The classroom unit ventilators are not able to support filtration in excess of MERV 8. All replacement filters for the UV’s should meet MERV 8 requirements.

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 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 viruses’ ability to infect.

WPS has begun to incorporate Bipolar Ionization extensively throughout the Thorndyke Road 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 Thorndyke Road School appear to have systems with the potential to comply with current ventilation codes, pending balancing and verification, 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 Thorndyke Road School to address the current pandemic condition.

Space	Exist. O.A. Vent. Systems	Recommendations
General Classrooms Older Section	Central Ventilation System	CCM - #1 & #2 Add filtration to central system. Art room requires dedicated exhaust. ECCM - #1 or #3 (*see note below)
Classrooms in Newer Section	Unit Ventilators	CCM - #1 & #2 ECCM - #1 or #3 (*see note below)
Offices	None	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 for 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 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)
- 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, where shown. 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 either radiators or unit ventilators. Ventilation to the building is split with the older original portion of the structure being served by a large central fan system located in the lower level which distributes air through ductwork to ventilation shafts. The system has a multi-section steam heating coil and appears to be capable of introducing large amounts of outdoor air. There were no air filters on this system. The fan appears to have a newer motor but was not operating the day of our inspection. The functionality of this system is unknown and should be tested.

A majority of the classrooms in the newer section of the building are ventilated and heated with classroom unit ventilators. The UV's are fitted with air 1" thick filters with an estimated MERV rating of 8 which is typical for units of this type. These units can support a maximum filter efficiency of MERV 8.

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 900 SF with 26 occupants (25 students + 1 teacher) would require 368 CFM of outdoor air (460 CFM if ZDE = 0.8). The existing drawings reflecting outdoor air ventilation rates showing 500 CFM for the unit ventilator systems which would exceed the code required outside air. Testing and Balancing of these and other systems, would be required to confirm outdoor airflow rates. There are no plans indicating existing airflow rates for the central system.

Bathroom and local exhaust requirements appear to be supported centrifugal exhaust fans of unknown capacity. Their proper operation should be confirmed.

Science & Art Rooms:

There are no assigned science rooms and one art room shown on the plans. 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. If the art room is to be used for that purpose, additional dedicated exhaust and make-up air ventilation would be required.

Offices:

The office areas do not appear to have any ventilation systems except that which is provided via operable windows and/or local exhaust either dedicated or from adjoining bathrooms. Positive air ventilation should be provided in these areas.

Controls:

Controls in the building appear to be fairly comprehensive however, control drawings provided do not show control of the central ventilation system. Further review of the existing controls with the control vendor would be required to verify the capabilities of the system to support some of the proposed measures such as CCM#1 and/or #2.

The energy management control system EMS is currently supported by Automated Building Systems, Inc (ABS).

The operating schedule for much of the equipment appears to be 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.

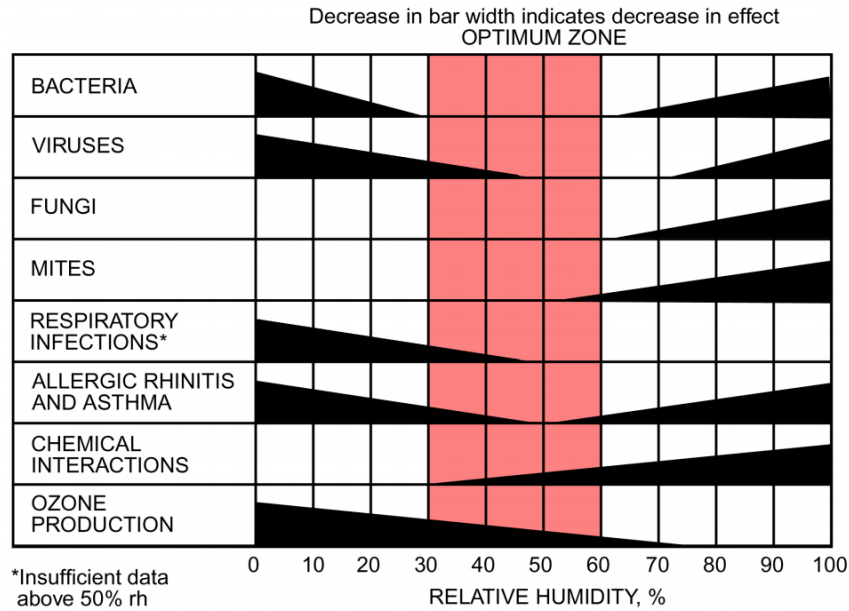


Fig. 1 Optimum Humidity Range for Human Comfort and Health
 (Adapted from Sterling et al. 1985)

The Thorndyke Road 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 Thorndyke Road 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 Thorndyke Road School have an outdoor air exchange rate near 3 for the rooms with unit ventilators and below 3 for the rooms without unit ventilators pending confirmation of the functionality and proper testing and control of the systems. 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.

Thorndyke Rd Elem. School IAQ Sampling Summary											
Space Tested	Temp.	Humidity	CO2	TVOC	HCHO	Room Area	Room Ht.	Volume	Design OA	OA Air	Notes
	°F	% RH	%	ppm	ppm	SqFt	Ft	Cubic Feet	CFM	ACH	
Basement Floor											
Library	73.4	31.1	480	1.5	0.1	986	11.5	11339	n/a	n/a	
Art Room	73.2	31.4	489	1.51	0.12	640	11.75	7520	n/a	n/a	
Computer Room	72.1	31.3	475	1.49	0.13	310	11.91	3692	n/a	n/a	
Cafeteria	73.5	31	464	1.45	0.09	1723	11.91	20521	n/a	n/a	
Kitchen	73.2	31.4	481	1.47	0.1	200	12	2400	n/a	n/a	
Gym/ All Purpose room	73.3	31.1	464	1.43	0.09	2187	12.91	28234	n/a	n/a	
Nurse	73.7	28.7	448	1.43	0.13	855	11.5	9833	n/a	n/a	
First Floor											
Main Office	78.5	26.3	564	1.56	0.14	281	11.33	3184	n/a	n/a	
Principal	80	24.9	508	1.55	0.12	307	11.33	3478	n/a	n/a	
Teachers Room	78.2	27.7	524	1.63	0.11	320	11.33	3626	n/a	n/a	
Classroom 4	79.8	31.3	507	1.52	0.12	746	11.5	8579	n/a	n/a	
Classroom 3	79.9	35.3	504	1.54	0.11	736	11.5	8464	n/a	n/a	
Classroom 7	77.4	27.9	529	1.6	0.13	739	11.5	8499	n/a	n/a	
Classroom 9	70.5	31.4	483	1.48	0.09	807	10.08	8135	500	3.7	
Classroom 12	70.8	33.3	521	1.52	0.2	949	10.08	9566	500	3.1	
Classroom 14	71	29.9	497	1.41	0.38	1231	10.08	12408	500	2.4	
Classroom 15	70.1	31.5	481	1.54	0.09	955	10.08	9626	500	3.1	

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.

We highly recommend at least minimum outdoor air be provided in areas which do not have such systems or if existing ventilation systems are not operational. For example, office areas should be supplied with OA ventilation as none appears to exist.

<u>Thorndyke Road School Ventilation System Summary</u>									
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
Classrooms (old)	N/A	N/A	N/A	N/A	N/A	N/A	#1, #2	#1, #3	a, c
Classrooms (newer)	N/A	N/A	N/A	varies	8	N/A	#1, #2	#1, #3	a
Offices +	N/A	N/A	N/A	N/A	N/A	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 for areas having none, even if via windows, as there is no substitute for proper ventilation regardless of other measures employed.
- c. CCM measure predicated on the existing system being operational and properly tested, balanced, and controlled.

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 Thorndyke Road 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 building areas are supported by a central ventilation system running under the lower floor and serving rooms via vertical shafts. The condition of this ventilation system is unknown however, there is a fan connected to this system which appears to be in operational order and as such, the building may be capable of this measure pending operational testing, balancing and control verification. The modular classroom units may be able to support this measure subject to capacity limitations.

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.

The building areas are supported by either classroom unit ventilators or a central ventilation system running in the basement level and serving rooms via vertical shafts. The condition of this ventilation system is unknown however, there is a fan connected to this system which appears to be in operational order. As such, the building may be capable of this measure pending operational testing, balancing and control verification.

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 section.

We were unable to locate air filters on the central ventilation system. However, if it is to remain in use filters should be added and the fan capability tested to confirm maximum filtration level. The classroom unit ventilators are not able to support filtration in excess of MERV 8. All replacement filters for the UV's should meet MERV 8 requirements.

B. ENHANCED HVAC COVID-19 CONTROL MEASURES

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

ECCM #1: Portable Room Purifiers

Portable room air purifiers could be used in select areas and rooms to help clean the air within 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: 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 Thorndyke Road Schools case they could be installed in the unit ventilator, RTU units as well as portable units may be considered. WPS has already begun to incorporate Bipolar Ionization extensively throughout the Thorndyke Road 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 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

Thorndyke Road School - Main Building

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									
				A	2.54	B	3.00	C	2.88	D	3.17	E	11.38	F	9.19	G	6.85	H	3.25	J	3.21	K	1.03	L	2.79	M	3.04					N	3.58	O	3.17	P	1.22	Q	0.97	
Basement																																								
Library	media	986	39.44																							6		6								39.75	-0.31	YES		
Art Room	classroom	640	25.6																									4			4					27.00	-1.40	YES		
Computer Room - A	classroom	310	12.4																														1			1.22	11.18	NO		
Computer Room - B	classroom	330	13.2																																	0.00	13.20	NO		
Kitchen Café Office	office	200	8																																0.00	8.00	NO			
Dry Storage	storage	111	4.44																																0.00	4.44	NO			
Storage off Boiler Room	storage	872	34.88																																0.00	34.88	NO			
Inner Storage	storage	96	3.84																																0.00	3.84	NO			
Custodian Office	office	94	3.76																																0.00	3.76	NO			
Music Room	classroom	653	26.12																							3							1			12.42	13.70	NO		
Nurse A	support	76	3.04																															1		2.79	0.25	NO		
Nurse B	support	69	2.76																															1		2.79	-0.03	YES		
Toilet	toilet	56	2.24																															1		2.79	-0.55	YES		
Gym / All Purpose / Book Room	multi	2187	87.48																							2							6			18.81	68.67	NO		
Gym - Storage	storage	60	2.4																																0.00	2.40	NO			
Cafeteria	café	1723	68.92																															6			16.75	52.17	NO	
Cafeteria - Stage	stage	301	12.04																																	0.00	12.04	NO		
First Floor																																								
Room 01	classroom	756	30.24																																		113.75	-83.51	YES	
Room 02	classroom	715	28.6																																		32.08	-3.48	YES	
Girl's Room	toilet	365	14.6																																	5.75	8.85	NO		
Storage	storage	40	1.6																																	0.00	1.60	NO		
Main Office Waiting Room	support	84	3.36																																	0.00	3.36	NO		
Main Office	office	197	7.88																																		8.08	-0.20	YES	
Custodian	support	50	2																																	0.00	2.00	NO		
Boy's Room	toilet	356	14.24																																	5.75	8.49	NO		
Room 03	classroom	736	29.44																																		32.08	-2.64	YES	
Room 04	classroom	746	29.84																																		113.75	-83.91	YES	
Room 05	classroom	746	29.84																																		113.75	-83.91	YES	
Room 06	classroom	739	29.56																																		113.75	-84.19	YES	
Principal's Office	office	307	12.28																																		64.31	-52.03	YES	A/C in one window.
Principal's Storage	storage	62	2.48																																	6.85	-4.37	YES		
Teacher's Room	support	320	12.8																																		73.50	-60.70	YES	
Teacher's Room Toilet	toilet	50	2																																	6.85	-4.85	YES		
Room 07	classroom	739	29.56																																		113.75	-84.19	YES	
Room 08	classroom	756	30.24																																		113.75	-83.51	YES	

Window Type	Width	Height	Projection	Venting
A - Awning	19	42	6	2.54
B - Awning	30	42	6	3.00
C - Awning	33	36	6	2.88
D - Awning	46	30	6	3.17
E - Awning	46	32	21	11.38
F - Awning	31	32	21	9.19
G - Awning	20	27	21	6.85
H - Awning	46	32	6	3.25
J - Hopper	50	27	6	3.21
K - Hopper	52	22	2	1.03
L - Awning	35	32	6	2.79
M - Awning	45	28	6	3.04
N - Awning	52	34	6	3.58
O - Awning	52	24	6	3.17
P - Hopper	54	34	2	1.22
Q - Hopper	52	18	2	0.97

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 windows or none present).

Thorndyke Road School - Addition

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
				A AWNING	2.79	B AWNING	2.13	C AWNING	2.19	D AWNING	2.29	E AWNING	2.35	F AWNING	2.46				
Ground Level																			
Room 09	classroom	807	32.28				3		3		3		3			26.88	5.41	NO	
Room 09 - Office	office	131	5.24				3		3							12.94	-7.70	YES	
Room 09A - Speech	support	156	6.24													0.00	6.24	NO	
Room 10	classroom	950	38				6		6		3		3			39.81	-1.81	YES	
Room 10 - Boy's Room	toilet	41	1.64													0.00	1.64	NO	
Room 10 - Girl's Room	toilet	41	1.64													0.00	1.64	NO	
Room 10A - Paper Supply	support	119	4.76													0.00	4.76	NO	
Room 11	classroom	950	38				6		6		3		3			39.81	-1.81	YES	
Room 11A - Custodian Closet	storage	25	1													0.00	1.00	NO	
Room 12	classroom	949	37.96				6		6		3		3			39.81	-1.85	YES	
Room 12 - Boy's Room	toilet	41	1.64													0.00	1.64	NO	
Room 12 - Girl's Room	toilet	41	1.64													0.00	1.64	NO	
Room 12A - Literature Tudor	classroom	154	6.16													0.00	6.16	NO	
Room 13	classroom	1061	42.44								9		9			41.81	0.63	NO	
Room 13 - Toilet	toilet	86	3.44													0.00	3.44	NO	
Room 13A - Custodian	support	40	1.6													0.00	1.60	NO	
Room 14	classroom	1231	49.24				6		6		3		3	9		61.94	-12.70	YES	
Room 14 - Supplies	storage	77	3.08													0.00	3.08	NO	
Boy's Room + Vestibule	toilet	323	12.92		2											5.58	7.34	NO	
Girl's Room + Vestibule	toilet	269	10.76		2											5.58	5.18	NO	
Room 15	classroom	955	38.2				6		6		3		3			39.81	-1.61	YES	
Room 16	classroom	955	38.2				6		6		3		3			39.81	-1.61	YES	
Room 16A - Storage	storage	38	1.52													0.00	1.52	NO	
Learning Coach	support	160	6.4		2											5.58	0.82	NO	
Psychology Room	support	69	2.76		1											2.79	-0.03	YES	
Psychology - Toilet	toilet	35	1.4		1											2.79	-1.39	YES	
Adjustment Counselor	support	72	2.88		1											2.79	0.09	NO	
Adjustment Counselor - Toilet	toilet	35	1.4		1											2.79	-1.39	YES	

Window Type	Width	Hieght	Projection	Venting
A - Awning	38	29	6	2.79
B - Awning	31	20	6	2.13
C - Awning	31	21.5	6	2.19
D - Awning	35	20	6	2.29
E - Awning	35	21.5	6	2.35
F - Awning	30	29	6	2.46

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)