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HVAC Report – Quincy Public School Buildings

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Design Overview of Building HVAC Systems

The HVAC designs utilized in our school buildings are diverse and span decades (Table 1). Older buildings utilize steam heating systems, low speed exhaust fans along with induced draft ventilation, and lack mechanical cooling. Our newer buildings utilize high efficiency hot water heating systems, energy recovery ventilators in conjunction with exhaust fans, and mechanical cooling/dehumidification. As a result of this diversity, each building system type requires a different approach to maintain systems and to adjust these systems for extraordinary situations such as COVID19. Regardless of building age or design, all school buildings are ventilated.

Our oldest of buildings were originally designed with heating and ventilation systems only. These buildings are equipped with simple or legacy control systems with little capability for adjustment. These buildings provided heat by burning coal to generate steam. The steam was directed throughout the buildings via a network of pipes feeding cast iron radiators to heat spaces throughout. Over the years these heating plants have been retrofitted to burn #4 heating oil, then #2 heating oil, and finally natural gas. Many of the cast iron radiators have been replaced with unit ventilators; in some cases the cast iron radiators were retained to function as back-up heating units. The unit ventilators provide heat, air circulation, outdoor air, and filtration. The ventilation in these buildings was originally accomplished using 1 or more large, low speed, built-in-place, exhaust fan(s). Rooms throughout the building are ducted to the fan plenum room where the fan draws from and expels the exhaust air through a shaft to the roof. Additionally, there were radiators located within shafts that connected occupied spaces to the roof. In the winter, the hot radiators would induce a draft, drawing outside air into the building and expelling exhaust air to the roof. Manually operated dampers would be adjusted to increase or decrease the air flow rate as desired. This was similar to turning up your heat and then opening the windows to regulate the amount of air you let in/out. The unit ventilators and newer roof-mounted exhaust fans take the place of the draft induction system to deliver the fresh air and exhaust the stale air.

Our newest buildings were designed with heating, energy recovery ventilation, and cooling/dehumidification systems. These buildings are equipped with modern control systems which are required to control the multiple and complex building HVAC systems. Buildings in this category were constructed after the mid-2000s. These buildings utilize high efficiency, natural gas fired, hot water boilers to generate heat. The hot water is circulated through a network of pipes to supply radiant heat panels, VAV re-heat coils, fan coil units, air-handling units, roof top units, and energy recovery ventilators to heat the building. The ventilation in these buildings is accomplished with a combination of roof-mounted exhaust fans and roof-mounted energy recovery ventilators (ERV). The exhaust fans generally service restrooms, custodial closets, and mechanical/electrical rooms. These fans remove air from these spaces by drawing air from elsewhere in the building. The ERVs serve occupied spaces such as classrooms, cafeteria, and locker rooms. These units exhaust stale air and replenish the spaces with fresh air. In this process, the energy level in the exhausted air is recovered, reducing the required new energy to condition the fresh air. After the recovery, the air is heated or cooled/dehumidified to the appropriate conditions to introduce to the space. This heating or cooling/dehumidifying process in the ERVs is referred to as tempering. Some spaces in these buildings are fully conditioned without the use of energy recovery. These spaces are typically computer labs, staff rooms, and other non-instructional spaces. In general, this is accomplished using fan coil units or packed roof top units.

Several of our school buildings are designed with elements of the old and new designs along with several features unique to the era. These buildings are equipped with legacy control systems or have been retrofitted with more modern control systems as part of a retro-commissioning process. Buildings in this grouping were constructed or renovated in the 1990s or 2000s. These buildings utilize standard efficiency, natural gas fired, hot water boilers to generate heat. The hot water is circulated through a network of pipes to supply unit ventilators, fin tube radiation, fan coil units, air handling units, roof top units, and make-up air units to heat the building. The unit ventilators, air handling units, roof top units, and make-up air units are equipped with outdoor air connections and deliver the fresh air that is circulated throughout the building and ultimately removed by the exhaust system. The ventilation in these buildings is accomplished using roof-mounted exhaust fans. These fans remove air from these spaces by drawing air from elsewhere in the building, all of which originates from outdoors. Cooling these buildings is accomplished using chiller units to generate chilled water or by self-contained unit ventilators which have built in mechanical cooling. The chilled water buildings circulate chilled water in the summer though the same pipes that circulate hot water in the winter. Using the same piping network reduces construction costs but requires a manual change-over twice annually. The cooling/dehumidification process is delivered to the spaces using the same units that provide heat in the winter.

Demand Control Ventilation (DCV)

Demand control ventilation is a method of controlling ventilation rates to reduce energy. This control method is relatively new and has now been a standard in ventilation control for 10 or

20 years. Prior to DCV, a building was designed to have a minimum volume of outdoor air delivered regardless of occupancy levels or building use. This would result in appropriate levels of ventilation during full occupancy and far more ventilation than would be required during times of low or no occupancy. Conditioning ventilation air from outdoor air conditions to normal building temperatures during hot or cold weather accounts for a large portion of energy associated the HVAC systems. In a DCV design, the minimum outdoor air levels are very low and in some cases 0%. Integral to this design is the monitoring of Carbon dioxide (CO_2) levels in the building (measured in parts per million (ppm)). CO_2 is a universally accepted method of measuring indoor air quality (IAQ). Indoor CO_2 levels increase as people in a building exhale. When a building is unoccupied or the occupancy is low, the CO_2 level remains low. When the building occupancy increases the level of CO_2 rises. In a DCV design, the minimum volume of outdoor air is increased proportionally with the CO_2 level up to the maximum volume of outdoor air. As the ventilation rate increases in response to the CO_2 level, the CO_2 level begins to decrease. Once the CO_2 level has returned to an acceptable level, the outdoor air volume returns to the minimum level to conserve energy.

Air Filtration

All heating/cooling/dehumidifying units are equipped with air filtration. The filtration process is designed to increase indoor air quality by reducing particulate in the air and to protect the components of the unit from becoming fouled over time. Most of the filters used are disposable and are replaced 3 times per year or more often if they become fouled more quickly. Some smaller units are equipped with washable filters. These filters are removed and washed at the same frequency.

Air filters are manufactured with different media to achieve a specific MERV (Minimum Efficiency Rating Value) rating. Developed from ASHRAE's (American Society of Heating, Refrigeration, and Air Conditioning Engineers) Standard 52.2 (Note 1), the MERV rating system assigns a number based on the filters ability to catch particulate of a certain size range (Table 2). The higher the MERV rating the smaller particulate the filter will catch and vs. The selection of a MERV rating for a filter system within an HVAC unit is completed during the HVAC system design process. During this process there are factors that drive the selection such as: building/space use, equipment type, fan energy, pressure drop across the filter, space constraints, particulate exposure/environment, outdoor/indoor air volumes etc. For a typical commercial building such as an office or school or library, the standard level of filtration is MERV 8. Residential filtration is also commonly MERV 8 when houses have air conditioning (AC) and less than MERV 8 in the case of a forced hot air furnace without AC. Our school buildings are designed to utilize MERV 8 filters.

Utilizing filters corresponding to the filter rating selected during the HVAC system design is always recommended, however; using a higher rated filter is possible. A higher MERV rated filter will filter out smaller particulate but it will have a higher pressure drop across the filter which will reduce the overall air flow rate unless the unit can compensate by increasing the fan speed. A decrease in air flow could result in a decrease in the ability to properly heat, cool, and ventilate a space. A higher rated filter will catch more particles and therefore foul more quickly, requiring an increase in filter changing frequency. It is worth noting that the particle size of aerosol COVID19 is not widely accepted and some reports indicate it can be as small as 0.1 microns (Note 2). This means that even the highest rated filter (E1 or MERV 16) would not necessarily stop all virus aerosol molecules.

Ultra Violet (UV) Light and Needlepoint Bipolar Ionization (NPBI)

UV light has long been the standard in a medical environment to eliminate viruses, bacteria, and fungal organisms. Implementing a UV strategy would be difficult in our buildings. UV could be installed in every air handling unit, unit ventilator, fan coil unit, roof top unit, etc. to treat the passing air. UV could also be used in the space to treat the surfaces similar to the process used in hospital operating rooms. Robots are now being built to allow automated room exposure during unoccupied periods. It is important to understand for a UV light strategy to be effective, surface disinfection requires every surface in a space to be exposed to the light for a prescribed period of time. This may result in slow-paced disinfection of large buildings with numerous obstacles/critical surfaces, like a school. Effective air stream disinfection using UV requires the room air to pass through the UV-equipped air handling equipment slowly enough to allow for the UV to be effective. This may prove difficult to accomplish in air handling equipment such as unit ventilators and fan coil units which are compact by design. Other factors to consider include: the expense of UV systems, the significant maintenance required, the significant power required, and PPE (personal protective equipment) required for anyone planning to be exposed to the UV light.

Bipolar ionization is an emerging method of disinfecting. The ionization process has improved and is now accomplished without the undesirable generation of ozone which occurred in order technologies. This technology uses electrodes in the air handling equipment to generate positively and negatively charged ions that travel into the air stream. These ions attach to particles, pathogens, and gas molecules. By attaching to submicron particles the bond creates larger molecules that either fall out of the air stream or are caught in air filters. The ions kill pathogens by robbing them of hydrogen to render them harmless. This technology is emerging and therefore does not have numerous studies backing the technological claims. Similar to UV systems, these systems can be expensive and would be retrofitted in all air handling equipment. Notable differences between the systems are: the electrical requirements and maintenance requirements are far less than that of UV and the NPBI system provides surface disinfecting in the space without the need for separate system.

Efforts Underway

Exhaust Fans and ERVs – The process of surveying, documenting, and making necessary repairs to the exhaust and ERV systems in each of the school buildings is underway. Ensuring these systems are operating properly is the most important step in ventilating buildings. For every unit volume of air removed from a building, an equal volume of fresh air is drawn into the building from outdoors. Normally these systems are repaired as problems are identified and reported through the work order system. Last summer we began a proactive approach to exhaust system maintenance at Beechwood Knoll Elementary where we serviced, repaired, adjusted, and documented all roof-top exhaust fans. Since this pilot and prior to local COVID19 concerns, we had rolled out similar efforts in 5 additional schools. This process will be applied to all schools including returning to the first 6 schools to ensure repairs are current. For all buildings with adjustable control systems, the hours of operation of exhaust fans and ERVs will be increased. This will "pre-purge" the building prior to occupancy and "post-purge" the building following occupancy. For buildings without adjustable control systems and without local timing devices, these systems will be modified to operate 24 hours per day. These changes will result in an energy penalty but will ensure the building spaces are ventilated beyond the design levels.

Demand Control Ventilation (DCV) – Buildings with DCV will be adjusted to reduce the levels of CO2 required for the associated increase in outdoor air volume. The EPA (Environmental Protection Agency) and ASHRAE are recommending operating DCV systems to maintain 800-1000ppm of CO2. Currently, our buildings are programmed to maintain 800ppm. We plan to reprogram the systems to maintain even lower rates than 800ppm. This change will result in an energy penalty but will ensure the building spaces are ventilated beyond the design levels.

Filtration Changes – Our current filter changing process ensures that all filters are changed just prior to the September start of school. We are in the process of evaluating which pieces of equipment in each school will accept a higher MERV rating filter. Based on the ASHRAE recommendations, we are evaluating for MERV 13 filters. These filters are reported to be approximately 50% efficient at capturing aerosols consistent with COVID19 and 95% efficient after 3 air turn overs in the space (Note 3). Our filter supplier has indicated there is a national shortage of filter media causing lead times to be longer than normal. We are actively discussing alternatives with our filter supplier.

Equipment Scheduling – In addition to increasing the operating schedules of exhaust fans and ERVs, other mechanical equipment responsible for introducing outdoor air into the building will be programmed for extended hours.

Ionization – We are in the process of evaluating the application of this technology to school buildings. This includes how to retrofit our equipment, which equipment would be outfitted, electrical impacts, costs, lead times, project management, and operation.

Window Installations – New operable windows have been ordered for several spaces in ground or basement levels of Montclair and Atherton Hough Elementary School. Aside from providing daylight where there was none, the occupants of these spaces will have the option to open the windows as desired to increase ventilation.

ERV Installations – Last year we installed ventilation units in the ground floor of Wollaston School. These units now provide ventilation to spaces that were not designed originally to house instructional space. This summer, as part of the renovation efforts, we are adding an additional unit at Wollaston and installing 2 new ERVs in the ground level of Montclair School to serve the new or updated instructional spaces.

Window Opening – In addition to the efforts previously listed to increase building ventilation, opening windows is available to building occupants. This may result in conditioning challenges in some spaces particularly when outdoor conditions are extreme however it will increase ventilation rates.

Notes:

1. ASHRAE standard 52.2 establishes 3 particle size ranges: E1 = (0.3-1.0 micron), E2 = (1.0 – 3.0 micron), and E3 = (3.0-10.0 microns)
2. US National Library of Medicine, National Institute of Health
3. AAF (American Air Filter Company) Flanders

Definitions

Ventilation - Ventilation is defined as the circulation of air or means of providing fresh air. For the purposes of this report, ventilation will refer to the means of providing fresh air.

Exhaust Fan (EF) – An exhaust fan is a motor-powered fan unit that takes air from a space and exhausts it outdoors.

Energy Recovery Ventilator (ERV) – An ERV is a unit that removes air from a space and replaces it with relative equal amounts of outdoor air. In the air exchange process, a means of energy recovery is utilized to transfer the energy from the exhausted air stream to fresh air stream. In the winter the energy flows from exhaust to fresh air. In the summer the energy flows from the fresh air to the exhausted air.

Air Handling Unit (AHU) – An AHU is any HVAC unit that contains a fan used to move air. For the purposes of this report, an AHU will be defined as an indoor unit with a fan, heating coil, sometimes a cooling coil, and a filter system.

Unit Ventilator (UV) – A UV is a small AHU similar to an FCU except the UV is capable of delivering and regulating an outdoor air component to the space.

Fan Coil Unit (FCU) – An FCU is essentially a smaller AHU and contains many of the same components.

Roof Top Unit (RTU) – An RTU is an HVAC unit that mounts outdoors on the roof and is ducted into the building to condition the space. RTUs can be packaged, off-the-shelf units or custom or semi-custom built for the application. Some typical features of an RTU are: fan or fans, heating, cooling, filtration, energy recovery, control dampers.

Variable Air Volume (VAV) – Variable Air Volume describes an HVAC system which varies the volume flow rate of air delivered to a space based on the needs of that space.

Reheat Coil (RH) – A hot water coil placed in a ducted air steam after a piece of air handling equipment to raise the temperature of the air delivered to a space.

Radiant Heat Panel (RHP) – A flat plate-type panel typically placed in a ceiling or a wall equipped with a conductive heat source on the back side of the panel. For this report, the heat source is forced hot water.

Chiller – A unit that cools water, typically using the refrigeration cycle, which is circulated throughout a building to be used to by HVAC equipment to provide cooling and dehumidification to a space.

Table 1 – Heating, Ventilation, and Cooling Systems by School Building

Quincy Public School Buildings					
Location	**Heating Plants**	**Terminal Heating Units**	**Ventilation Systems**	**Cooling Systems**	**Note**
Della Chiesa, ECC	2, N.G.- fired, cast iron, HW boilers	Unit Ventilators	Exhaust Fans	Unit Ventilators, FCUs	
Atherton Hough	2, N.G.- fired, cast iron, steam boilers	Unit Ventilators, Radiators, AHU	Exhaust Fans	None	
Beechwood Knoll	3, N.G-fired, HE, HW boilers	Unit Ventilators, AHU	Exhaust Fans	Unit Ventilators, PTACs	
Bernazzani	3, N.G-fired, HE, HW boilers	Unit Ventilators, AHUs	Exhaust Fans	None	
Lincoln-Hancock	Electric resistance, N.G-fired furnaces	Unit Ventilators, AHUs	Exhaust Fans	None	
Clifford Marshall	2, N.G-fired, cast iron, HW boilers	Unit Ventilators, RTUs	Exhaust Fans	Unit Ventilators, RTUs	
Merrrymount	2, N.G.- fired, cast iron, steam boilers w/HW HX	Unit Ventilators, AHUs, RTU	Exhaust Fans	None	
Montclair	2, N.G.- fired, cast iron, steam boilers	Unit Ventilators, Radiators	Exhaust Fans	None	
Parker	2, N.G.- fired, cast iron, steam boilers w/HW HX	Unit Ventilators, Radiators, AHUs	Exhaust Fans	4 Basement Rooms	
Snug Harbor	2, N.G.- fired, cast iron, steam boilers w/HW HX	Unit Ventilators, Radiators, FCUs, AHUs	Exhaust Fans	None	
Squantum	2, N.G.- fired, cast iron, steam boilers w/HW HX	Unit Ventilators, Radiators, AHUs	Exhaust Fans	None	
Wollaston	2, N.G.- fired, cast iron, steam boilers	Unit Ventilators, Radiators, AHU	Exhaust Fans	None	
Atlantic	2, N.G.- fired, cast iron, steam boilers	Unit Ventilators, Radiators, AHUs	Exhaust Fans	None	
Broad Meadows	3, N.G-fired, HE, HW boilers	Unit Ventilators, FCUs, AHUs	Exhaust Fans, ERVs	None(Existing), ERVs(New)	1
Central	3, N.G-fired, HE, HW boilers	VAV w/RH, RHP, FCUs, AHUs	Exhaust Fans, ERVs	ERVs, RTUs, FCUs	
Point-Webster	2, N.G-fired, cast iron, HW boilers	Unit Ventilators, FCUs, AHUs		Unit Ventilators, AHUs	
SouthWest	3, N.G-fired, HE, HW boilers	VAV w/RH, RHP, FCUs, AHUs	Exhaust Fans, ERVs	ERVs, RTUs, FCUs	
North Quincy High	5, N.G-fired, HE, HW boilers	Unit Ventilators, FCUs, AHUs w/RH	Exhaust Fans	Unit Ventilators, AHUs	
	2, N.G-fired, cast iron, HW boilers				
GOALS	Electric resistance, N.G-fired furnaces	Electric baseboard, FHA	Exhaust Fans	RTUs	
Quincy High	5, N.G-fired, HE, HW boilers	VAV w/RH, RHP, FCUs, AHUs	Exhaust Fans, ERVs	RTUs, FCUs	

Legend	**General Notes:**	**Notes:**
N.G. = Natural Gas	Small hallway and storage area heating units are not included	1. Broad Meadows is mid-renovation
HE = High Efficiency	Small, single room cooling systems are not included	
HW = Hot Water		
HX = Heat Exchanger		
AHU = Air Handling Unit		
RTU = Roof Top Unit		
FHA = Forced Hot Air		
VAV = Variable Air Volume		
RH = Reheat Coil		
RHP = Radiant Heat		
ERV = Energy Recover Ventilator		
PTACS = Packaged Terminal Air Conditioner		

Table 2: MERV Ratings, Airex Filter Corporation, QPS Air Filter Supplier

AIREX FILTER
CORPORATION

MERV (Minimum Efficiency Reporting Value)	Composite Average Particle Size Efficiency, % in size, µm			Average Arrestance, %	Size of contaminant that can be captured
	0.3-1.0	1.0-3.0	3.0-10.0		
1	-	-	20% or Better	65% or Less	Lint
2	-	-	20% or Better	65%-69%	Pollen
3	-	-	20% or Better	70%-74%	Bugs
4	-	-	20% or Better	75% or Greater	Sanding Dust
5	-	-	20%-34%	-	Cement Dust
6	-	-	35%-49%	-	Mold Spores
7	-	-	50%-69%	-	Gelatin
8	-	20% or Better	70% or Better	-	Powder
9	-	35% or Better	75% or Better	-	Milled Flour
10	-	50%-64%	80 or Better	-	Auto
11	20% or Better	65%-79%	85% or Better	-	Emissions
12	35% or Better	80% or Better	90% or Better	-	Fumes
13	50% or Better	85% or Better	90% or Better	-	Bacteria
14	75%-84%	90% or Better	95% or Better	-	Tobacco
15	85%-94%	90% or Better	95% or Better	-	Smoke
16	95% or Better	95% or Better	95% or Better	-	Talcum Dust