INDOOR AIR QUALITY IMPROVEMENT STUDY

JANUARY 21, 2020

Perkins&Will

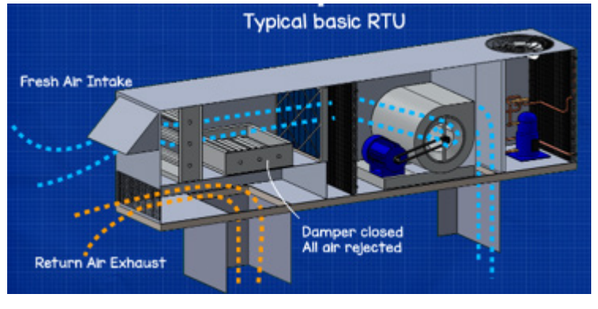
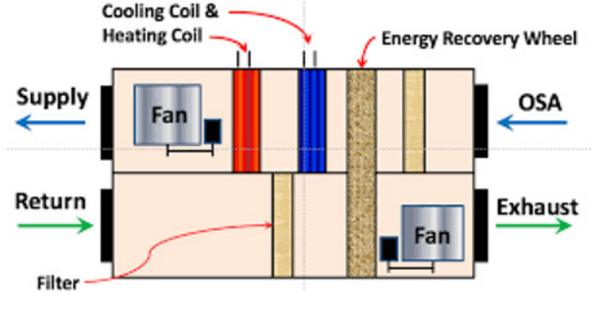
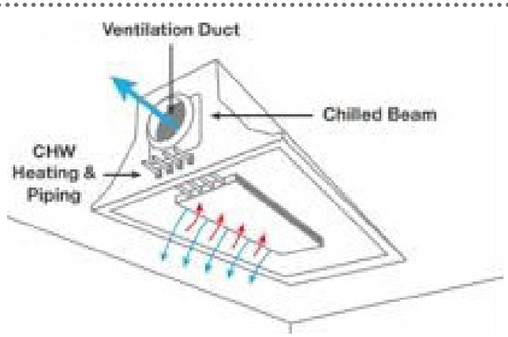
BMHS BUILDING HVAC DESIGN

- Primary focus of building HVAC systems design was the reduction of energy use, with the goal of achieving a Zero Net Energy building.
- Ventilation design per MA code and meets LEED requirements
- Ventilation design is in line with similar high performance schools

IMPROVING INDOOR AIR QUALITY IN RELATION TO PANDEMICS

- Increase amount of outside air wherever possible
- Increase filter efficiency
- Modify controls/systems to be able to flush out spaces
- Introduce technologies to break down contaminants

HVAC SYSTEM DESIGN

BUILDING HVAC SYSTEM TYPES		CURRENT SYSTEM NOTES	POTENTIAL STRATEGIES
Mixed / Recirculation Systems • Auditorium/ Stage/ Commons • Black Box/ Music • Field House/ Small Gym • Pool		• Ventilation rates in excess of code requirements • Currently have MERV 13 filters	• Increase filter to MERV 14 • No Demand Control Ventilation (DCV) • Extended Hours of Operation • Increased Outdoor Air • Bipolar Ionization
Dedicated Outside Air Systems • Classrooms • Administration Offices • Fitness • Locker Rooms		• Ventilation rates in excess of code requirements • Currently have MERV 13 filters	• No Demand Control Ventilation (DCV) • Extended Hours of Operation • Increased Outdoor Air • Bipolar Ionization
VAV/ Chilled Beam Units • Classrooms • Media • Work/ Group Spaces		• Optimal energy saving system • Very quiet • No filtration at chilled beam	• No Demand Control Ventilation (DCV) • Extended Hours of Operation • Bipolar Ionization
Admin. VRF Fan Coil Units • Ducted Fan Coil Units • Ductless Ceiling Cassettes		• Currently have MERV 8 filters (ducted units) • Allows to operate independent of main system in summertime	• Increase filter to MERV 13 • No Demand Control Ventilation (DCV) • Extended Hours of Operation • Bipolar Ionization

HVAC IAQ IMPROVEMENT STRATEGIES

CONTROLS STRATEGIES

No Demand Control Ventilation (DCV)

- Override of demand control ventilation within the spaces to provide the maximum amount of fresh air regardless of space occupancy.
- This strategy can be effective for providing additional fresh air to flush out spaces and lower contaminant concentrations within spaces.

Extended Hours of Operation

- Run the ventilation systems 2 hours prior and post occupancy.
- Allows for additional space flush out before and after the school day, and applies to all of the systems

Increased Outside Air Ventilation

- Increase the amount of outside air provided for the mixed air systems.
- An effective amount of outside air can be provided when outside air conditions are optimal and also if slightly warmer or cooler space conditions are allowed. Only applies to the mixed air systems.

EQUIPMENT STRATEGIES

Increase System's Filter Efficiency

- Increase unit final filters from MERV-13 to MERV-14. Increase the VRF Fan Coil units filters from MERV-8 to 2in MERV-13 type filters.
- Can increase the effectiveness for the capture of small particles from 75% to 90%. Comes with slight energy penalty due to higher pressure drop across the filter.

Add portable air purifiers

- Provide portable air purifiers that include HEPA type filtration (IQAir HealthPro Plus or equal)
- Air purifiers with HEPA filtration effectively capture small particles up to over 99%. Would require periodic changing of numerous filters.

Add Bipolar Ionization

- Install duct mounted bipolar ionization devices at each single zone air handling unit and at each VAV terminal unit
- Bipolar ionization is very effective at breaking down viruses. Provides heavy particles for the virus to adhere to. This forces the heavier particles to drop out of the airstream and particles that remain are more effectively filtered.

Portable Air Purifier

Bipolar Ionization Applied to Duct

Bipolar ioniation Bar

	Total Energy (MMBtu)	% Difference	Total Cost ($)	% Difference	EUI
PROPOSED DESIGN	13,447	0.0%	662,857	0.0%	29.9
No DCV	14,313	-6.4%	705,371	-6.4%	31.8
No DCV + Ext Hours	15,794	-17.5%	769,767	-16.1%	35.1
INCREASE OA	13,626	-1.3%	672,368	-1.4%	30.3
No DCV + Ext Hours + Inc OA	16,065	-19.5%	784,065	-18.3%	35.7
BIPOLAR IONIZATION	13,448	0.0%	662,912	0.0%	29.9
STANDALONE AIR PURIFIERS	13,743	-2.2%	675,310	-1.9%	30.5

Energy Model Study

- Based on the strategies available, individual study cases were established to compare to the baseline of the current energy model
- Controls strategies are identified as separate options as well as combined if all three are implemented.

Energy Model Results

- Bipolar and Air Purifiers have little to no impact on energy use
- Increase of Outside Air has minimal impact due to limited allowable systems
- No Demand Control and Extended Hours of operation have biggest impact due to affecting all systems

Evaluation Cases	Number of Wells	Peak EWT				Average EWT			
		Max. Peak EWT (°F)	@ Month	Min. Peak EWT (°F)	@ Month	Max. Ave EWT (°F)	@ Month	Min. Ave EWT (°F)	@ Month
Design Case – Jan. 2020 100% CD Loads	**280**	**85.5**	**357**	**45.5**	**1**	**72.2**	**357**	**50.4**	**1**
Baseline - Proposed Nov. 2020	280	80.3	357	45.8	1	69.2	357	50.5	1
Case 1 - Proposed - No DCV	280	79.4	357	45.5	1	68.7	357	50.2	1
Case 2 - Proposed - Ext Hrs + No DCV	280	73.7	357	44.6	1	63.7	357	49.0	1
Case 3 - Proposed - Increased OA	280	79.1	357	45.5	1	68.0	357	50.2	1
Case 4 - Proposed - Ext Hrs, No DCV, Inc OA	280	72.4	357	44.3	1	62.0	357	48.6	1

Consumption (MMBtu)						
CASES	Jan 2020 100% CD Loads	Baseline - Proposed November 2020	Case 1- Proposed - No DCV	Case 2- Proposed - Ext Hrs + No DCV	Case 3 - Proposed - Increased OA	Case 4 - Proposed - Ext Hrs, No DCV, Inc OA
CHW LOOP	5254	4743	4,897	5185	4783	5,251
HW LOOP	(3792)	(3966)	(4,393)	(6397)	(4349)	(6,987)
POOL HTG LOOP	(977)	(761)	(761)	(761)	(761)	(761)
DHW LOOP	(297)	(296)	(296)	(296)	(296)	(296)
Cooling Load on Well Loop	330	408	408	556	406	553
Balance	518	128	(146)	(1714)	(218)	(2,239)

Geothermal Wellfield Study

- The hourly loads for each case provided by the energy model results were processed for wellfield modeling to evaluate the potential impacts to the performance of the geothermal system.

Geothermal Model Results

- Maximum peak EWT for cooling mode is reduced when the load balance improves or shifts from cooling dominant to heating dominant. (Max. allowable 85.5°F)
- The minimum peak EWT values for heating in the proposed cases reduce slightly or stay the same to the Design Case, but are still above the specified minimum EWT limit (40°F)
- The proposed cases have no impact on the design of the geothermal well field, and in some cases improve the balance of the system. Both the max. and min. peak EWT for all proposed cases are within the EWT constraints specified.

GEOTHERMAL WELL MODEL RESULTS

	IAQ Improvement Strategy	Description	Effectiveness	Energy Use Intensity (EUI)	EUI Delta from Current Design	Effect on Geothermal Well Field	Operating Cost (Annual)	Operating Cost Delta from Current Design (%)	Additional Estimated Capital Cost	Additional Estimated Design Fee
	Current Design			29.9	N/A	No Impact	$662,857	N/A	None	None
1	**Add Portable Air Purifiers**	Provide portable air purifiers that include HEPA type filtration (IQAir HealthPro Plus or equal) Provide 2 units each classroom up to 1,200sf. Provide 1 units for small spaces up to 600sf High School already owns 148 units.	Air purifiers with HEPA filtration effectively capture small particles up to over 99%. Units are set at middle/low setting for acoustic purposes. For small to medium sized rooms, such as offices and classrooms, this is an effective way to increase air quality. For large spaces will require a large number of units.	30.5	2.2%	No Impact	$675,310 $120,000 additional per yr to change filters (400 units)	1.9%	Phase-1 Delta: $95,000 (80 units) Phase-2: $200,000 (172 units) (incl. Skanska markups)	None
2*	**Increase System's Filter Efficiency**	Increase unit final filters from MERV-13 to MERV-14. Increase the VRF Fan Coil units filters from MERV-8 to 2in MERV-13 type filters. Possible to swap out filter types only when needed, instead of always using the higher efficiency filters.	Increasing the unit filters to MERV-14 can increase the effectiveness for capture of small particles from 75% to 90%. For the ducted VRF units, increasing the filtration to 2" MERV-13 filters will greatly increase the effectiveness of the terminal units. This will have slight effect on airflow due to larger pressure drop.	Minimal Impact	Minimal Impact	No Impact	Minimal Impact $20,000 add. premium annually for filters	Minimal Impact	$25,000	None
3a*	**No Demand Control Ventilation (DCV)**	Override of demand control ventilation within the spaces to provide that maximum amount of fresh air regardless of space occupancy. Can implement the ability and use as needed, instead of all the time (i.e. pandemic mode)	This strategy can be effective for providing additional fresh air to flush out spaces and lower contaminant concentrations within spaces.	31.8	6.4%	Improves system balance	$705,371	6.4%	$15,000	$1,500
3b*	**No DCV + Extended Hours of Operation**	Override of DCV noted above Run the ventilation systems 2 hours prior and post occupancy. Can implement the ability and use as needed, instead of all the time (i.e. pandemic mode)	The extended hours strategy applies to all of the systems. Allows for additional space flush out before and after the school day.	35.1	17.5%	Improves system balance	$769,767	16.1%	Included in cost of Option 3a	$1,500
3c*	**No DCV + Extended Hours of Operation + Increased Outside Air Ventilation**	Strategy includes the two strategies noted above Increase the amount of outside air provided for the mixed air systems. Can implement the ability and use as needed, instead of all the time (i.e. pandemic mode)	The increased ventilation strategy only applies to the mixed air systems capable of economizer mode. An effective amount of outside air can be provided when outside air conditions are optimal and also if the allowable temperature conditions can allow for slightly warmer or cooler space conditions.	35.7	19.5%	Improves system balance	$784,065	18.3%	Included in cost of Option 3a	$1,500
4a	**Bipolar Ionization Full Building Option**	Install duct mounted bipolar ionization devices at each single zone air handling unit and at each VAV terminal unit (for mult-zone units).	Bipolar ionization is very effective at breaking down viruses such as COVID-19. Provides heavy particles for the virus to adhere to. This forces the heavier particles to drop out of the airstream and be more effectively filtered.	29.9	0%	No Impact	$662,857	0%	$600,000 Excludes $75k for alarming feature	$24,000
4b	**Bipolar Ionization Large Volume Spaces Option**	Provide bipolar ionization only at large volume spaces where portable air purifier application is not practical.	See above option 4a.	29.9	0%	No Impact	$662,857	0%	$80,000 Excludes alarming	$15,000

* Shaded rows represent items previously approved at 12/18/2020 BMHSBC meeting

COMPARING AIR PURIFIERS AND BIPOLAR IONIZATION

IAQ Improvement Strategy	Description	Pros	Cons
Option 1 - Add Portable Air Purifiers	Provide portable air purifiers that include HEPA type filtration (IQAir HealthPro or equal) Units with UV, photocatalytic oxidation, and/or ionization are available but not necessary where HEPA filtration is provided. Multiple levels of pre-filtration typical in addition to HEPA.	Can be implemented on a temporary or permanent basis. Practical solution for improving air quality in small to medium sized spaces.	Initial Capital Cost (based on full implementation) Maintenance – Pre-filter replacement each year, HEPA filter replacement every 2 to 3 years (varies by manufacturer) Noise (operation on medium speed recommended) Effectiveness is localized in larger spaces
Option 4 - Bipolar Ionization	Pro-active method for directly attacking viruses in the occupied space. Install duct mounted bi-polar ionization devices at each single zone air handling unit. Install duct mounted bi-polar ionization devices at each VAV terminal unit. Install duct mounted bi-polar ionization devices at each ducted VRF fan coil terminal unit. Provide needlepoint type bi-polar ionization devices for each ductless VRF cassette fan coil terminal unit.	Once implemented, always functional Very low energy required No noise impacts Low maintenance (maintenance check every year) Based on manufacturer's testing, effective at inactivating viruses Enhances filtration capability due to agglomeration of particulates.	Initial Capital Cost Effectiveness information is limited to manufacturer's or third party test data

MANUFACTURER'S SPECIFICATIONS ON LONGEVITY OF AIR PURIFIERS

Warranty: 10 years **Pre-filter Replacement:** Every 16 months **HEPA filter replacement:** 3 years and 9 months

QUALITY OF AIR IMPROVEMENTS WITH BIPOLAR IONIZATION

The bi-polar ionization (BPI) device is mounted in the supply ductwork of the HVAC system. Airflow passes by the ionization device and energizes the air to form bi-polar — positive and negative — air ions. The airflow distributes the energized ions into the spaces served by the HVAC system. Unlike many other types of air purification systems, the bi-polar ions proactively seek out and neutralize the contaminants at the source in the space itself. When positive or negative ions come into contract with a virus particle, they interact with the receptor proteins on the outside cell wall of the virus causing them to be destroyed. This causes the virus to lose the ability to bind with human cells which prevents the virus RNA from getting into the cells.

Historically, bi-polar ionization has been applied in HVAC systems to reduce airborne particulates, control odors due to VOCs, reduce mold, and reduce biofilms on cooling coils. The reduction of particulates and VOCs from ionization is typically applied as an alternate ASHRAE ventilation procedure to reduce the amount of outside ventilation air in HVAC systems to reduce energy consumption. Prior to the pandemic, the use of BPI for controlling airborne virus transmission was very limited, but was well known as a potential strategy through research. BPI was mentioned in publications as early as 2009 for reducing virus transmission and there have been numerous research reports citing the effectiveness of ionization on the ability to inactivate viruses. Further research is needed to better quantify the effects of virus neutralization from interaction with ions in a typical indoor environment, but it is clear that the application leads to healthier indoor air.

Based on discussion with Atmosair (leading BPI manufacturer), here are some systems installations for schools since the start of the pandemic:

a. The Pingry School in NJ (already installed and operational)

b. Neshaminy School District in PA (installation began in November)

c. Auburn School District in MA (ordered but not installed yet).

RERESENTATIVE AIR CHANGE RATE CALCULATIONS

Total number of air changes per hour is determined for outside air plus recirculated air filtered to MERV 13 efficiency or greater. Recommended guidelines from the Healthy Buildings Program of the Harvard T.H. Chan School of Public Health state that 4 to 5 ACH is Good and 5 to 6 ACH is Excellent.

		HVAC System			Air Purifier Set to Medium Speed (180 cfm)		HVAC + Air Purifiers	
Room Type	**System**	**Outside Air Quantity (cfm)**	**Return Air Quantity (with MERV-13 filter)**	**Air Change Rate (ACH)**	**Quantity**	**ACH**	**Total ACH**	**With 100% Outside Air Increased Ventilation Total ACH Option 3c**
Classroom	DOAS/Active Chilled Beam	395	0	2.77	2	2.53	5.3	
Administrative Office	Ducted VRF	15	95	3.14	1	6.55	9.7	
Band Room	AHU	1,195	1,360	3.31			3.3	3.8*
Orchestra	AHU	731	960	2.51			2.5	2.9*
Black Box	AHU	960	3,900	3.48			3.5	4.3*
Auditorium	RTU	4,325	6,105	3.58			3.6	4.2*
Cafe Commons	RTU	2,536	6,780	4.79			4.8	5.9*
Science Classrooms	DOAS/Active Chilled Beam	1,290	0	6.23			6.2	
Art Room	DOAS/Active Chilled Beam	890	0	4.09	2	1.65	5.7	
Locker Room	HVAC	550	550	5.11			5.1	
Field House	H&V	9,600	22,400	2.47			2.5	3.0*
Small Gym	H&V	1,200	6,800	2.87			2.9	3.6*
Weight / Cardo	Multi Split	1,000	0	2.63	3	2.60	5.2	
Fitness	Multi Split	410	0	3.95	1	3.18	7.1	

* NOTE ON LARGE VOLUME SPACE: Portable air purifier application is not practical. Where portables are not used bi-polar ionization is recommended to be installed for these systems to help increase indoor air quality effectiveness. Total ACH for Increased Ventilation based on 100% outside air whenever conditions permit. The large volumes of these spaces provides additional dilution of contaminants to lower levels beyond what the total air change rate may indicate.