IAQ Verification Report

Marlborough Elementary School

IAQ Verification

Marlborough, CT

SES Project No. 25-381

October 1, 2025

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Executive Summary

Sustainable Engineering Solutions, LLC (SES) and Trueflow Testing and Balancing were retained by the Town of Marlborough to provide professional engineering and test and balancing (TAB) services to meet the indoor air quality (IAQ) verification requirements of the state legislation Public Act No. 23-167 at the Marlborough Elementary School facility. This combined effort successfully completed the required verification as outlined in the legislation. With a focus on validating and improving indoor air quality, SES and Trueflow systematically assessed each air handling system to measure current ventilation rates, filtration rates and distribution levels compared to current ventilation standards.

The evaluation confirmed that while the facility can achieve code-required ventilation rates with corrective actions, nearly all major HVAC systems including rooftop units, air handling units, and classroom unit ventilators were installed in 2002 and are at or beyond their expected useful life. The age and condition of this equipment should be recognized as the primary finding of this study and a central focus for future capital planning.

In the absence of an imminent building renovation or system replacement, this report provides a set of lower-cost, targeted measures designed to stabilize IAQ and maintain compliance with ASHRAE 62.1 and state code. Recommended actions include replacing failed CO2 sensors, rebalancing airflows, correcting demand control ventilation sequences, servicing inoperable supply fans, recalibrating VAVs, upgrading filters to MERV 13, and repairing exhaust fans. These measures address immediate ventilation shortfalls and improve filtration while deferring major capital investment.

Particular attention is given to the classroom unit ventilators, which have widespread operational and comfort issues. SES does not recommend further investment in repairing these units due to persistent noise, heating control deficiencies, and mechanical failures. Instead, their replacement should be incorporated into the next facility renovation or modernization project. As an interim solution, portable filtration units may be deployed in classrooms to improve air cleaning capability.

In summary, the near-term strategy is to implement the recommended corrective measures to stabilize ventilation performance and prepare for comprehensive HVAC replacement as part of a broader capital improvement plan. This approach balances occupant health, regulatory compliance, and fiscal prudence while minimizing the risk of sunk costs in equipment that is approaching the end of serviceable life.

Note that throughout this report the term “ventilation” air and “outside” are used interchangeably and are one in the same.

IAQ Verification Process

Filter Evaluation

As required by the law, the team reviewed the current level of filtration installed on each air handling system and analyzed the feasibility of increasing the filter ratings to MERV 13. A filter’s minimum efficiency reporting value, or MERV, is a rating system that measures how efficient a filter is at trapping harmful particulate matter, dust, and debris in the air. This rating system categorizes filters into a ranking from 2 to 20, with a MERV 8 being the standard. A higher MERV rating means that a

filter is more efficient and MERV 13 is recommended for many commercial and industrial buildings and by state code. At its minimum, a MERV 13 filter traps less than 75% of air particles that are 0.3 to 1.0 microns in size and is at least 90% effective when the particles increase to 3 to 10 microns in size. Along with assessing the filter efficiencies, the condition of unit's filters and proper sealing of the filter banks to eliminate bypass air was also evaluated.

Ventilation Evaluation

The amount of ventilation air delivered into interior occupied spaces is governed by the 2022 Connecticut State Building Code, which references ASHRAE Standard 62.1. This code prescribes the flow rate of ventilation air that must be supplied mechanically, or otherwise, to occupied areas based on occupancy classifications. Depending on the type of use of a space and total space area, outdoor air flow rates in cubic feet per minute (CFM) per person and square foot are defined when the parameters are known. When total occupants per space are unknown, the code defines occupant density for each classification type in number of occupants per space floor area. The final flow rate in CFM for every occupied space can thus be calculated.

As an alternative to providing outside air mechanically to occupied spaces, the building code also allows for outside air to enter occupied areas naturally through operable windows. If the area of operable windows for an occupied space is at least 4% of the space's floor area, mechanical ventilation for that space is not required by code. However, although spaces with sufficient operable window area may satisfy code requirements, this is not a realistic way of providing adequate ventilation during periods of cold or hot weather.

The amount of outside air supplied to occupied spaces is important for occupant comfort and health because contaminants generated by people and materials in the space must be removed or they will build up to unhealthy levels. Diluting interior air with outside air reduces the concentration of carbon dioxide, volatile organic compounds (VOCs) along with various airborne viral and bacterial contaminants.

Demand Control Ventilation

In certain applications, the amount of outside air delivered to a space can be reduced if occupancy and indoor air quality can be safely monitored and controlled. This is most typically accomplished through monitoring carbon dioxide (CO2) and occupancy sensors in the space, otherwise known as "Demand Control Ventilation" or DCV. As occupancy rises in a space, so does the amount of CO2 as a result of the occupant's natural respiration and exhalation of CO2. By monitoring CO2 and occupancy status, an HVAC system can reduce the amount of outside air to a zone when levels and occupancy are low. If CO2 levels rise above a certain threshold or occupancy is detected, the HVAC system can then increase the amount of fresh air until the levels fall back below an acceptable level. Having an operational demand control ventilation strategy in place will help reduce energy consumption of a facility while simultaneously ensuring all spaces are achieving the required fresh air requirements.

Project Approach

During the review of the school, SES took the following steps to complete the study:

- Develop an IAQ evaluation plan and conduct a kickoff meeting with the client and Trueflow to review the plan, project schedule, access, etc.
- Perform a walkthrough of the building to review the HVAC systems providing ventilation air for a condition assessment of the systems and understand any maintenance issues that may be related.
- Review available documentation for the HVAC systems that includes:
    - As-built drawings or original design drawings
    - O&M documentation for systems performance data
    - Review any previous testing adjusting and balancing reports from the HVAC systems
    - Review documentation describing the chronology of known problems, system failures, complaints, and alterations.
- Develop IAQ evaluation documentation for field evaluation of equipment.
- Perform field evaluation of equipment for ventilation sequence of operation and verify calibration of CO2 sensors where used (+/- 50 PPM).
- Review Trueflow's completed ventilation rate verification sheets for each space for compliance with ASHRAE 62.1
- Review the Trueflow's completed unit data sheets for each system providing ventilation air for ventilation airflows, filter condition and efficiency, damper conditions and maintenance adequacy.
- Prepare a report that summarizes the verification process, identifies any deficiencies that require correction and any recommendations to address the deficiencies found and next steps.

Participants

The participants in the IAQ verification process for this project are identified below.

Owner

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Facility Description

Building

Building:	Marlborough Elementary School
Location:	25 School Dr, Marlborough, CT 06447
Building Size (gross):	105,870 ft^2
Year Constructed:	1949; renovated in 2002
Building Use (current):	Education



The 105,870 square foot Marlborough Elementary School building was originally constructed in 1949 and provides a learning space for Kindergarten through 6th grade. The facility underwent a complete renovation in 2002. The building consists of classrooms, administration offices, gymnasium, cafeteria, media center and other typical educational spaces.

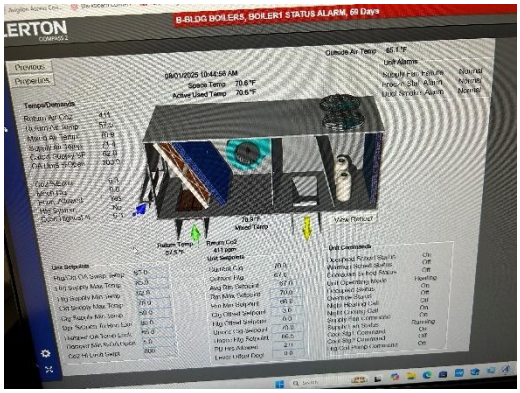
Occupancy

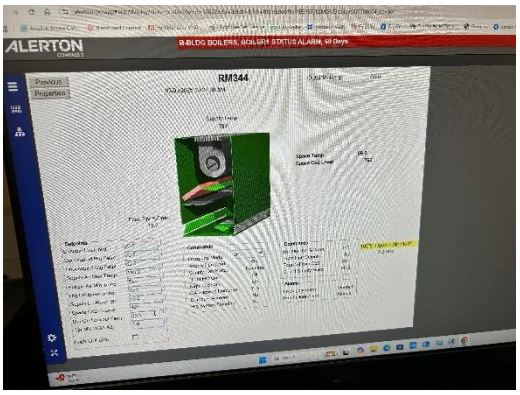
The building is occupied Monday through Friday between 7 a.m. and 4 p.m. Special events are held on the weekends and after hours as needed for school extracurricular activities. In addition, the school hosts summer school activities during the summer break.

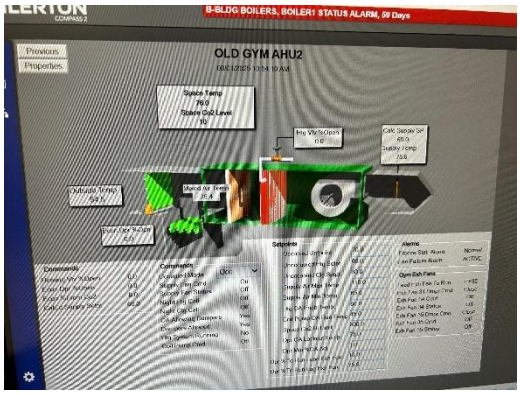
Building Automation System Description

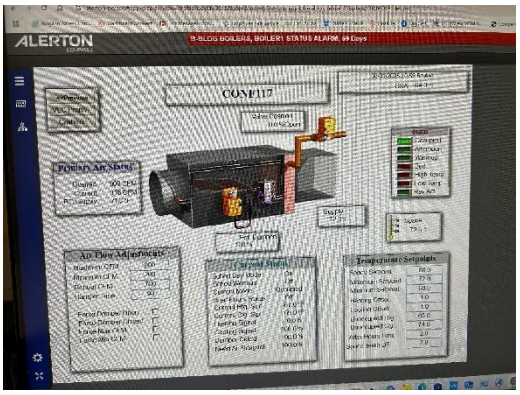
The HVAC system is controlled by a Allerton Compass 2 building automation system. This system has graphics for all the HVAC equipment and is capable of trending and performing custom control algorithms. Example graphics have been included below. Overall the control system is original to 2002 and many of the controllers, devices and software are no longer supported.

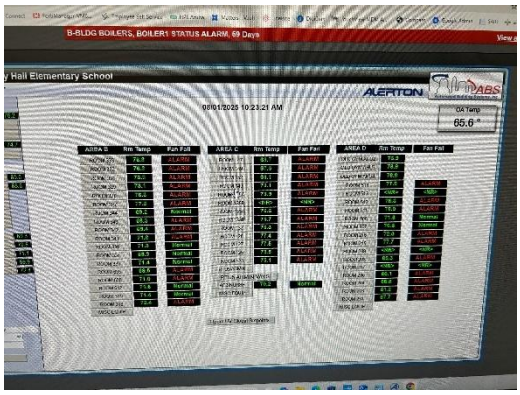












HVAC Systems Description

Rooftop Units

In total, there are eight (8) rooftop units (RTUs). Of the eight RTUs, one is a multizone variable-air-volume (VAV) unit that serves VAV boxes. The remaining RTUs are constant-volume and serve single zones.

For the multizone VAV RTU, airflow to the space is controlled by the VAV box with ventilation air being provided and controlled by the RTU. As the heating and cooling requirements of the space change, the VAVs adjust the total airflow introduced in the space. The air entering the VAV box is served by the associated rooftop unit. The rooftop unit mixes return air from the building with fresh outside air, filters the airstream and then conditions it by heating or cooling as necessary. As the airflow requirements of the spaces change, the supply fan of the unit will increase and decrease speed accordingly.

For the single zone units, the spaces are conditioned and ventilated by the associated unit. The unit mixes return air from the space with fresh outside air, filters the airstream and then conditions it by heating or cooling as necessary at a constant airflow.

All units maintain a fixed minimum outside air damper setpoint but are equipped with return air carbon dioxide (CO2) sensors for demand control ventilation. As the CO2 in the building rises above the setpoint, the outside air damper will modulate from minimum setpoint to 100% open. Once CO2 levels fall below setpoint, the outside air damper will modulate back towards minimum position.

Originally installed in 2002, the roof top units are beyond their useful life expectancy and have reached the age of replacement.

Unit Tag	Serves	Type	Min OA Damper Setpoint	CO2 Setpoint
RTU-1	Gym	Single Zone	30%	800 PPM
RTU-2	Stage	Single Zone	30%	800 PPM
RTU-3	Cafeteria	Single Zone	15%	2000 PPM
RTU-4	Art Room	Single Zone	10%	650 PPM
RTU-5	Administration	Multi Zone	15%	2000 PPM
RTU-6	Library / Media Center	Single Zone	10%	650 PPM
RTU-7	Computer Lab	Single Zone	10%	650 PPM
RTU-8	BLDG “B” Core Area	Single Zone	15%	2000 PPM





RTU-1 (serving Gym) *RTU-2 (serving Stage)*



RTU (typ. RTU-3 thru 8)

Air Handling Units

In total, there are four (4) air handling units (AHUs) in the facility that serve single zones.

These spaces are conditioned and ventilated by the associated unit. The unit mixes return air from the space with fresh outside air, filters the airstream and then conditions it by heating as necessary at a constant airflow. As the space requires cooling and heating, the unit's supply fan will modulate speed between a minimum and a maximum setpoint.

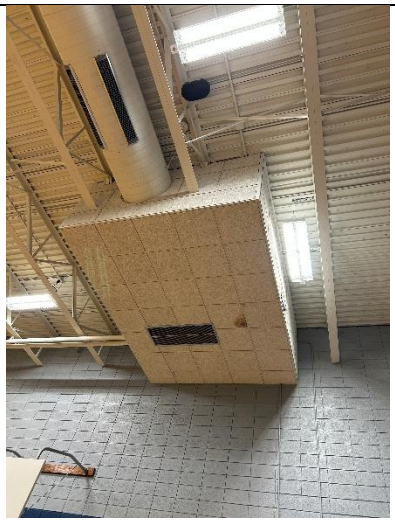
These units are heating-only type and do not provide any means of mechanical cooling to the space.

All units maintain a fixed minimum outside air damper setpoint but are equipped with return air carbon dioxide (CO2) sensors for demand control ventilation. As the CO2 in the building rises above the setpoint, the outside air damper will modulate from minimum setpoint to 100% open. Once CO2 levels fall below setpoint, the outside air damper will modulate back towards minimum position.

Originally installed in 2002, the air handling units are beyond their useful life expectancy and have reached the age of replacement.

Unit Tag	Serves	Type	Min OA Damper Setpoint	CO2 Setpoint
AHU-1	Boiler Room	Single Zone	100%	-
AHU-2	Gym	Single Zone	15%	800 PPM

Unit Tag	Serves	Type	Min OA Damper Setpoint	CO2 Setpoint
AHU-3	Gym	Single Zone	15%	800 PPM
AHU-4	Gym	Single Zone	15%	800 PPM



Gymnasium AHU (typ. of 3)

Unit Ventilators

The majority of the spaces are all served by unit ventilators. These unit ventilators are installed on exterior wall of the associated spaces and provide heating and ventilation only to these spaces. Each space is also equipped with a CO2 sensor, which increases the amount of ventilation air introduced into the space once levels rise above setpoint.

These units are heating-only type and do not provide any means of mechanical cooling to the space.

Originally installed in 2002, the unit ventilators are beyond their useful life expectancy and have reached the age of replacement.





Unit Ventilator (typ.)

Exhaust Fans

In total there are thirty-three (33) exhaust fans installed throughout the building. These fans provide the required exhaust airflows to the classroom and facility bathrooms.



Rooftop Exhaust Fans (typ.)

Recommendations

The following recommendations were made based on the review of TAB report, ventilation comparisons to the IMC Minimum Ventilation Rates (2021) and industry best practices. Additional supporting information can be found in the Appendices of the report.

Due to the limited area of focus of the required IAQ verification and this review, SES strongly recommends verifying the condition of all related HVAC equipment components and control functionality outside of the scope of this verification, prior to implementing any modifications to the HVAC systems.

Recommendation #1: Replace CO2 Sensors

The following CO2 sensors (26 total) were found to be failed and requiring replacing. These CO2 sensors must be operable for the demand control ventilation described further below in the report to properly operate.

SES recommends replacing the following sensors:

**Note: The costs of replacing Unit Ventilator CO2 sensors should be assessed against any upcoming plans for replacements. Refer to Recommendation #8 for further information.*

Served	BAS Reading	Field Measurement
RTU-1 New Gym	725 PPM	520 PPM
RTU-2 Stage	750 PPM	520 PPM
AHU-2, 3 & 4 Old Gym	10 PPM	500 PPM
AC-3 Nurse	2,040 PPM	510 PPM
UV RM 333	800 PPM	480 PPM
UV RM 332	837 PPM	490 PPM
UV RM 331	807 PPM	480 PPM
UV RM 329	1,088 PPM	470 PPM
UV RM 328	10 PPM	490 PPM
UV RM 344	785 PPM	500 PPM
UV RM 343	780 PPM	480 PPM
UV RM 342	803 PPM	460 PPM
UV RM 341	0 PPM	470 PPM
UV RM 336	817 PPM	470 PPM
UV RM 638	853 PPM	490 PPM
UV RM 642	943 PPM	500 PPM
UV RM 319	0 PPM	490 PPM
UV RM 135A	233 PPM	470 PPM
UV RM 135B	0 PPM	470 PPM
UV RM 133B	605 PPM	470 PPM

Served	BAS Reading	Field Measurement
UV RM 513	0 PPM	490 PPM
UV RM 209	0 PPM	490 PPM
UV RM 207	0 PPM	480 PPM
UV RM 204	646 PPM	460 PPM
UV RM 203	2,048 PPM	450 PPM
UV RM 231	1,931 PPM	450 PPM

Recommendation #2: Rebalance Air Handler Outside Airflows and Reprogram Demand Control Ventilation

The RTUs & AHUs are currently equipped with demand control ventilation and CO2 monitoring. Under normal conditions, the units operate at the minimum outside air damper position (MIN-OAD). When space CO2 levels exceed the setpoint, the outside air damper modulates to the maximum damper position (MAX-OAD) to increase ventilation. As CO2 levels drop below the setpoint, the damper position returns to MIN-OAD.

Under the current configuration, SES identified various issues with the current outside airflow levels, CO2 setpoints and associated demand control ventilation programming. These issues included improperly set CO2 setpoints, outside air dampers not responding to CO2 controls and minimum outside air levels below the required minimum.

In order for the units to provide the required ventilation levels and properly adjust outside air levels based on CO2 levels; the following procedures should be followed as outlined below for all units globally:

- A TAB contractor should determine new MIN-OAD and MAX-OAD damper percentages that correspond to the airflows listed in the table below.
- The following sequence of operations should be programmed for the units as follows by a Controls contractor:
    - *"Under normal conditions, the unit operates at the minimum outside air damper position (MIN-OAD). When space CO2 levels exceed the setpoint, the outside air damper modulates to the maximum damper position (MAX-OAD); subject to a low mixed air temperature of 50°F (adj.). As CO2 levels drop below the setpoint, the damper position returns to MIN-OAD."*
- The MIN-OAD and MAX-OAD damper position setpoints should be incorporated into the BAS sequence, ensuring alignment with the new demand control ventilation logic.

**NOTE: RTU 2 & 3 scope of work is dependent on Recommendations 3 & 4 being addressed*

Proposed Setpoints				
Unit Tag	Serves	CO2 Setpoint	MIN-OAD (CFM)	MAX-OAD (CFM)
RTU-1	New Gym	1,200 PPM	420	2,480
RTU-2*	New Stage	1,200 PPM	90	630
RTU-3*	Cafeteria	1,200 PPM	950	2,740

Proposed Setpoints				
Unit Tag	Serves	CO2 Setpoint	MIN-OAD (CFM)	MAX-OAD (CFM)
RTU-4	Art Room	1,200 PPM	330	860
RTU-5	Admin	1,200 PPM	210	520
RTU-6	Media	1,200 PPM	520	1,230
RTU-7	Computer Lab	1,200 PPM	100	330
RTU-8	Reading	1,200 PPM	180	400
AHU-2	Gymnasium	1,200 PPM	120	490
AHU-3	Gymnasium	1,200 PPM	120	490
AHU-4	Gymnasium	1,200 PPM	120	490

Recommendation #3: Service RTU-2 Supply Fan

During the survey investigation the TAB contractor noted that RTU-2's supply fan was not operational.

SES recommends that the supply fan be serviced and repaired to ensure proper airflow to the area.

Recommendation #4: Service RTU-3 Supply Fan

During the survey investigation the TAB contractor noted that RTU-3 was only able to produce 2,200 CFM of supply airflow. Per the original design documents, RTU-3 should have the capability to provide 6,000 CFM to the space.

SES recommends that RTU-3 be further reviewed and investigated to determine if the supply airflow can be increased to provide the required levels of outside airflow.

Recommendation #5: Rebalance Nurse Office AC-3

During the survey investigation AC-3 serving the Nurses Office was found to be providing no outside air to the space by the TAB contractor. Per the BMS graphic, this unit has a single open / close minimum outside air damper.

SES recommends rebalancing the minimum outside air damper and return air dampers to achieve the following minimum outside airflow.

Unit Tag	Serves	Minimum Outside Airflow (CFM)
AC-3	Nurse	320 CFM

Recommendation #6: VAV Recalibration

The survey revealed that the majority of the VAVs served by RTU-5 were found to be out of calibration.

SES recommends the following VAV controllers be assessed by a Controls contractor to confirm the controllers are in operable condition. Once operation is confirmed, the VAVs should be recalibrated to accurately measure the required airflows and achieve their associated airflow setpoints.

Space	Desired Airflow Setpoint (CFM)	BMS Airflow (CFM)	TAB Measured Airflow (CFM)
SRO 119	500	56	349
Conference Room 117	200	235	421
Main Office 106	700	582	1110
Work Room 109	700	582	458
Assistant Principal's Office 108	500	514	149
Principal's Office 107	500	514	204
Board of Education Office 102	500	521	128
Superintendent Office 103	500	521	115
Records 104	500	521	87
Pupil Services Office 105	500	521	76
OPS 113	100	121	62

Recommendation #7: Filter Improvements

Currently all the RTUs and AHUs have a mixture of filters including MERV 8 and MERV 11; many which are dirty and require replacing.

SES recommends replacing and upgrading all final filters to MERV 13 for increased filtration efficiency and to satisfy the CT State Requirements.

Recommendation #8: Replace Existing Unit Ventilators

The majority of classroom unit ventilators were found to be manually disabled due to persistent noise, comfort, and mechanical issues, with several units inoperable because of electrical or component failures. Given their age, lack of cooling capability, and poor heating control, these units are considered beyond their useful life. SES does not recommend further investment in repairs or upgrades, as end users are likely to continue bypassing the equipment even if limited fixes are made.

SES recommends planning for full replacement of the unit ventilators with a modern HVAC system as part of the school's next renovation or capital improvement project. As an interim measure, the district may consider deploying portable filtration units in classrooms to improve air cleaning and maintain acceptable indoor air quality until permanent system replacement occurs.

Recommendation #9: Spaces Without Mechanical Ventilation

Several classrooms were identified as lacking any dedicated means of mechanical ventilation, relying solely on exhaust fans and operable windows to provide outside air. While this approach satisfies code under mild weather conditions, it leaves the spaces without adequate ventilation during periods of hot or cold outdoor temperatures.

Room #	Required Outside Airflow (CFM)
202	100 CFM

Room #	Required Outside Airflow (CFM)
212	60 CFM
218	120 CFM
303	250 CFM
335	110 CFM

SES recommends addressing these deficiencies as part of a future capital improvement project by replacing the existing unit ventilators with a modern HVAC system capable of delivering consistent ventilation, heating, and cooling. As an interim measure, portable filtration units may be deployed in the affected classrooms to supplement air cleaning and help maintain acceptable indoor air quality until permanent upgrades are implemented.

Recommendation #10: Service & Repair Exhaust Fans

The majority of exhaust fans were found to be inoperable, resulting in restroom exhaust rates below required code levels. Several fans were commanded "ON" by the BAS but failed to operate due to mechanical or electrical issues. SES recommends repairing or replacing the failed units and subsequently rebalancing the system to confirm all restrooms meet the required exhaust airflow.

The following exhaust fans were found to be inoperable:

EF Tag	BAS Command	Condition
8	Off	Failed
9	On	Failed
10	On	Failed
11	On	Failed
12	On	Failed
14	On	Failed
17	On	Failed
22	On	Failed
24	On	Failed
25	On	Failed
28	On	Failed
29	On	Failed
30	On	Failed
31	On	Failed
33	On	Failed

Once the exhaust fan repairs are made, the following restrooms require rebalancing to achieve the desired exhaust airflows:

Room #	Measured Airflow (CFM)	Required Exhaust Airflow (CFM)
115	0	25
114	0	25
124	0	25
126	0	25
225	0	25
224	0	25
223	0	150
222	0	150
151	0	25
148	0	25
324	0	200
325	0	200
348	0	25
349	0	25
623	0	25
622	0	25
637	0	25
639	0	25
643	0	25
603	53	150
605	26	150
611	0	25
612	0	25
517	0	25
506	0	150
505	0	150

Next Steps

Review Recommendations

It is recommended that the client review this report and the proposed recommendations for further clarification, if needed and decide a course of action. SES can provide additional assistance if needed, to further analyze and develop these recommendations for future implementation, and if desired, provide commissioning of the implemented measures.

Appendix A: IAQ Evaluation Sheet

Unit Tag	Room #	Category	ZoneArea, Az, per space (SF)	TAB Exhaust CFM	# of Toilets	Calc'd Exhaust CFM	Ventilation Difference (CFM)	Code Satisified?	Comments
-	141	Toilet rooms - private	105	105	1	25	80	Yes	
-	143	Toilet rooms - public	247	761	6	300	461	Yes	
-	129	Toilet rooms - public	254	499	6	300	199	Yes	
-	115	Toilet rooms - private	64	0	1	25	(25)	No	
-	114	Toilet rooms - private	64	0	1	25	(25)	No	
-	124	Toilet rooms - private	49	0	1	25	(25)	No	
-	126	Toilet rooms - private	49	0	1	25	(25)	No	
-	225	Toilet rooms - private	49	0	1	25	(25)	No	
-	224	Toilet rooms - private	49	0	1	25	(25)	No	
-	223	Toilet rooms - public	150	0	3	150	(150)	No	
-	222	Toilet rooms - public	150	0	3	150	(150)	No	
-	153	Toilet rooms - private	64	29	1	25	4	Yes	
-	151	Toilet rooms - private	49	0	1	25	(25)	No	
-	148	Toilet rooms - private	49	0	1	25	(25)	No	
-	324	Toilet rooms - public	189	0	4	200	(200)	No	
-	325	Toilet rooms - public	189	0	4	200	(200)	No	
-	362	Toilet rooms - public	189	370	4	200	170	Yes	
-	361	Toilet rooms - public	189	394	4	200	194	Yes	
-	348	Toilet rooms - private	53	0	1	25	(25)	No	
-	349	Toilet rooms - private	53	0	1	25	(25)	No	
-	623	Toilet rooms - private	95	0	1	25	(25)	No	
-	622	Toilet rooms - private	110	0	1	25	(25)	No	
-	637	Toilet rooms - private	49	-	1	25	(25)	No	
-	639	Toilet rooms - private	53	-	1	25	(25)	No	
-	643	Toilet rooms - private	53	-	1	25	(25)	No	
-	603	Toilet rooms - public	126	53	3	150	(97)	No	
-	605	Toilet rooms - public	126	26	3	150	(124)	No	
-	611	Toilet rooms - private	49	-	1	25	(25)	No	
-	612	Toilet rooms - private	49	-	1	25	(25)	No	
-	517	Toilet rooms - private	49	-	1	25	(25)	No	
-	506	Toilet rooms - public	150	-	3	150	(150)	No	
-	505	Toilet rooms - public	150	-	3	150	(150)	No	

Notes

No fresh air requirements for public bathrooms, only exhaust. Exhaust is 50 CFM or 70 CFM per water closet or urinal. If exhaust fan is intermittent than the higher value is used.

No fresh air requirements for private bathrooms, only exhaust. Exhaust is 25 CFM or 50 CFM per water closet or urinal. If exhaust fan is intermittent than the higher value is used.

No fresh air requirements for shower rooms, only exhaust. Exhaust is 20 CFM or 50 CFM per shower head. If exhaust fan is intermittent than the higher value is used.

Corridors are .06 CFM/sf only

Locker rooms are exhasut only at 0.5 CFM/sf

Corridors are .06 CFM/sf only

IMC 2021 Ventilation Assessment																		
Unit Tag	Room #	Category	Infiltration	ZoneArea, Az, per space (SF)	Zone Population, Pz, per space	People OA Rate in Breathing Zone, Rp (CFM/person)	Area OA Rate in Breathing Zone, Ra (CFM/SF)	Default Occupant Density	Populatation OA (Rp*Pz)	Area OA (Ra*Az)	Breathing Zone OA (CFM) Vbz=RpPz+RaAz	Table 6-2 Zone Air Distribution Effectiveness	Zone OA Flow, Voz	Min. Ventilation Airflow (CFM)	Actual Supply Airflow (CFM)	Outside Airflow (%)	Actual Ventilation Airflow (CFM)	Ventilation Difference (CFM)	Code Satisified?
AC-3	138	Daycare Sickroom	1	568	9	10	0.18	25	90	102	192	1	192	192	670	0%	-	(192)	No
AC-3	139	Daycare Sickroom	1	189	9	10	0.18	25	90	34	124	1	124	124	259	0%	-	(124)	No
AHU-2	Gymnasium	Multiuse assembly	0	1,916	50	7.5	0.06	100	375	115	490	1	490	490	4,958	21%	1,041	551	Yes
AHU-3	Gymnasium	Multiuse assembly	0	1,916	50	7.5	0.06	100	375	115	490	1	490	490	4,327	8%	346	(144)	No
AHU-4	Gymnasium	Multiuse assembly	0	1,916	50	7.5	0.06	100	375	115	490	1	490	490	2,048	4%	82	(408)	No
RTU-1	Community Room	Multiuse assembly	0	6,864	275	7.5	0.06	100	2063	412	2,474	1	2,474	2,474	5,667	0%	-	(2,474)	No
RTU-2	Stage	Stages, studios	0	1,495	54	10	0.06	70	540	90	630	1	630	630	-	0%	-	(630)	No
RTU-3	613	Cafeteria/fast-food dining	1	3,933	225	7.5	0.18	100	1688	708	2,395	1	2,395	2,395	2,737	14%	383	(2,012)	No
RTU-3	Kitchen	Kitchen (cooking)	0	1,280	14	7.5	0.18	20	105	230	335	1	335	335	867	14%	121	(214)	No
RTU-3	Kitchen Office	Office spaces	-	65	1	5	0.06	5	5	4	9	1	9	9	26	14%	4	(5)	No
RTU-4	315	Art Classroom	1	1,686	49	10	0.18	20	490	304	794	1	794	794	1,651	13%	215	(579)	No
RTU-4	Office	Classrooms (ages 5 to 8)	-	119	2	10	0.12	25	20	14	34	1	34	34	226	13%	29	(5)	No
RTU-4	311	Office spaces	0	194	4	5	0.06	5	20	12	32	1	32	32	104	13%	14	(18)	No
RTU-5	119	Office spaces	0	241	5	5	0.06	5	25	14	39	1	39	39	349	13%	45	6	Yes
RTU-5	117	Office spaces	0	320	10	5	0.06	5	50	19	69	1	69	69	421	13%	55	(14)	No
RTU-5	106	Reception areas	1	725	12	5	0.06	30	60	43	103	1	103	103	1110	13%	144	41	Yes
RTU-5	109	Conference rooms	1	437	5	5	0.06	50	25	26	51	1	51	51	458	13%	60	8	Yes
RTU-5	108	Office spaces	1	176	3	5	0.06	5	15	11	26	1	26	26	149	13%	19	(6)	No
RTU-5	107	Office spaces	1	280	8	5	0.06	5	40	17	57	1	57	57	204	13%	27	(30)	No
RTU-5	102	Reception areas	1	352	7	5	0.06	30	35	21	56	1	56	56	128	13%	17	(39)	No
RTU-5	103	Office spaces	1	280	4	5	0.06	5	20	17	37	1	37	37	115	13%	15	(22)	No
RTU-5	104	Office spaces	1	182	3	5	0.06	5	15	11	26	1	26	26	87	13%	11	(15)	No
RTU-5	105	Office spaces	1	190	4	5	0.06	5	20	11	31	1	31	31	76	13%	10	(22)	No
RTU-5	113	Office spaces	1	224	2	5	0.06	5	10	13	23	1	23	23	62	13%	8	(15)	No
RTU-6	302	Libraries	1	4,017	126	5	0.12	10	630	482	1,112	1	1,112	1,112	3,939	12%	473	(639)	No
RTU-6	304	Reception areas	0	216	12	5	0.06	30	60	13	73	1	73	73	146	12%	18	(55)	No
RTU-6	Next to 307	Office spaces	0	138	2	5	0.06	5	10	8	18	1	18	18	148	12%	18	(1)	No
RTU-6	Library	Office spaces	0	138	2	5	0.06	5	10	8	18	1	18	18	147	12%	18	(1)	No
RTU-7	346	Computer Lab	0	700	22	10	0.12	25	220	84	304	1	304	304	1,093	14%	153	(151)	No
RTU-7	Director of Operations	Office spaces	0	156	3	5	0.06	5	15	9	24	1	24	24	156	14%	22	(3)	No
RTU-8	364	Libraries	0	252	5	5	0.12	10	25	30	55	1	55	55	-	7%	-	(55)	No
RTU-8	354	Libraries	0	273	7	5	0.12	10	35	33	68	1	68	68	30	7%	2	(66)	No
RTU-8	352	Libraries	0	234	4	5	0.12	10	20	28	48	1	48	48	141	7%	10	(38)	No
RTU-8	366	Libraries	0	243	7	5	0.12	10	35	29	64	1	64	64	193	7%	14	(51)	No
RTU-8	356	Libraries	0	224	5	5	0.12	10	25	27	52	1	52	52	222	7%	16	(36)	No
RTU-8	357	Classrooms (ages 5 to 8)	0	198	6	10	0.12	25	60	24	84	1	84	84	230	7%	16	(68)	No
RTU-8	358	Office spaces	0	140	3	5	0.06	5	15	8	23	1	23	23	159	7%	11	(12)	No

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Unit Tag	Room #	Category	Infiltration	ZoneArea, Az, per space (SF)	Zone Population, Pz, per space	People OA Rate in Breathing Zone, Rp (CFM/person)	Area OA Rate in Breathing Zone, Ra (CFM/SF)	Default Occupant Density	Populatation OA (Rp*Pz)	Area OA (Ra*Az)	Breathing Zone OA (CFM) Vbz=RpPz+RaAz	Zone OA Flow, Voz	Min. Ventilation Airflow (CFM)	Actual Supply Airflow (CFM)	Actual Outside Airflow (CFM)	Actual Ventilation Airflow (CFM)	Ventilation Difference (CFM)	Code Satisified?	CFM per SF	Fan Speed	Notes
No mechanical ventilation	202	Conference rooms	1	406	14	5	0.06	50	70	24	94	94	94	0	0	-	(94)	No	24	N/A	
No mechanical ventilation	212	Conference rooms	1	306	8	5	0.06	50	40	18	58	58	58	0	0	-	(58)	No	18	N/A	
No mechanical ventilation	218	Classrooms (ages 9 plus)	1	300	8	10	0.12	35	80	36	116	116	116	0	0	-	(116)	No	36	N/A	
No mechanical ventilation	303	Classrooms (ages 5 to 8)	1	529	18	10	0.12	25	180	63	243	243	243	0	0	-	(243)	No	63	N/A	
No mechanical ventilation	335	Classrooms (ages 5 to 8)	1	459	5	10	0.12	25	50	55	105	105	105	0	0	-	(105)	No	55	N/A	
UV	123	Classrooms (ages 5 to 8)	1	1116	25	10	0.12	25	250	134	384	384	384	1568	0	-	(384)	No	134	low	
UV	125	Classrooms (ages 5 to 8)	1	1077	21	10	0.12	25	210	129	339	339	339	1310	75	75	(264)	No	129	low	
UV	127	Classrooms (ages 5 to 8)	1	711	12	10	0.12	25	120	85	205	205	205	1161	87	87	(118)	No	85	low	
UV	128	Classrooms (ages 9 plus)	1	696	24	10	0.12	35	240	84	324	324	324	0	0	-	(324)	No	84	Unit not operable	
UV	203	Classrooms (ages 5 to 8)	1	754	19	10	0.12	25	190	90	280	280	280	957	438	438	158	Yes	90	low	
UV	204	Classrooms (ages 5 to 8)	1	754	22	10	0.12	25	220	90	310	310	310	348	65	65	(245)	No	90	low	
UV	206	Classrooms (ages 9 plus)	1	754	19	10	0.12	35	190	90	280	280	280	0	0	-	(280)	No	90	Unit not operable	
UV	207	Classrooms (ages 9 plus)	1	754	20	10	0.12	35	200	90	290	290	290	0	0	-	(290)	No	90	Unit not operable	
UV	208	Classrooms (ages 9 plus)	1	754	19	10	0.12	35	190	90	280	280	280	792	441	441	161	Yes	90	low	
UV	209	Classrooms (ages 9 plus)	1	767	21	10	0.12	35	210	92	302	302	302	0	0	-	(302)	No	92	Unit not operable	
UV	215	Classrooms (ages 9 plus)	1	754	20	10	0.12	35	200	90	290	290	290	1503	415	415	125	Yes	90	Low	
UV	216	Classrooms (ages 9 plus)	1	754	18	10	0.12	35	180	90	270	270	270	1198	528	528	258	Yes	90	Med	
UV	231	Classrooms (ages 5 to 8)	1	477	12	10	0.12	25	120	57	177	177	177	965	228	228	51	Yes	57	low	
UV	132	Conference rooms	1	864	30	5	0.06	50	150	52	202	202	202	0	0	-	(202)	No	52	Unit not operable	
UV	133B	Music/theater/dance	1	1736	71	10	0.06	35	710	104	814	814	814	1612	718	718	(96)	No	104	low	
UV	133A	Music/theater/dance	1	1736	71	10	0.06	35	710	104	814	814	814	1552	420	420	(394)	No	104	low	
UV	135A	Music/theater/dance	1	900	51	10	0.06	35	510	54	564	564	564	1580	41	41	(523)	No	54	low	
UV	135B	Music/theater/dance	1	900	51	10	0.06	35	510	54	564	564	564	0	0	-	(564)	No	54	Unit not operable	
UV	152	Classrooms (ages 5 to 8)	1	974	18	10	0.12	25	180	117	297	297	297	1425	240	240	(57)	No	117	low	
UV	146	Classrooms (ages 5 to 8)	1	725	10	10	0.12	25	100	87	187	187	187	1007	126	126	(61)	No	87	low	
UV	149	Classrooms (ages 5 to 8)	1	960	18	10	0.12	25	180	115	295	295	295	1291	178	178	(117)	No	115	low	
UV	147	Classrooms (ages 5 to 8)	1	1073	18	10	0.12	25	180	129	309	309	309	1715	202	202	(107)	No	129	low	
UV	318	Classrooms (ages 9 plus)	1	738	20	10	0.12	35	200	89	289	289	289	1038	465	465	177	Yes	89	low	
UV	319	Classrooms (ages 9 plus)	1	811	21	10	0.12	35	210	97	307	307	307	0	0	-	(307)	No	97	Unit not operable	
UV	327	Classrooms (ages 9 plus)	1	765	14	10	0.12	35	140	92	232	232	232	736	588	588	356	Yes	92	low	
UV	328	Classrooms (ages 9 plus)	1	765	20	10	0.12	35	200	92	292	292	292	789	436	436	144	Yes	92	low	
UV	329	Classrooms (ages 9 plus)	1	765	19	10	0.12	35	190	92	282	282	282	1095	433	433	151	Yes	92	low	
UV	331	Classrooms (ages 5 to 8)	1	765	22	10	0.12	25	220	92	312	312	312	928	405	405	93	Yes	92	low	
UV	332	Classrooms (ages 5 to 8)	1	765	21	10	0.12	25	210	92	302	302	302	1135	478	478	176	Yes	92	low	
UV	333	Classrooms (ages 5 to 8)	1	765	22	10	0.12	25	220	92	312	312	312	1157	510	510	198	Yes	92	low	
UV	336	Classrooms (ages 5 to 8)	1	793	21	10	0.12	25	210	95	305	305	305	913	491	491	186	Yes	95	low	
UV	337	Classrooms (ages 5 to 8)	1	752	18	10	0.12	25	180	90	270	270	270	1283	149	149	(121)	No	90	med	
UV	339	Classrooms (ages 5 to 8)	1	803	22	10	0.12	25	220	96	316	316	316	1016	0	-	(316)	No	96	low	
UV	341	Classrooms (ages 5 to 8)	1	803	17	10	0.12	25	170	96	266	266	266	0	0	-	(266)	No	96	Unit not operable	
UV	342	Classrooms (ages 5 to 8)	1	803	16	10	0.12	25	160	96	256	256	256	248	46	46	(210)	No	96	low	
UV	343	Classrooms (ages 5 to 8)	1	803	15	10	0.12	25	150	96	246	246	246	1069	553	553	307	Yes	96	low	
UV	344	Classrooms (ages 5 to 8)	1	788	10	10	0.12	25	100	95	195	195	195	749	83	83	(112)	No	95	low	
UV	512	Classrooms (ages 9 plus)	1	754	22	10	0.12	35	220	90	310	310	310	0	0	-	(310)	No	90	Unit not operable	
UV	511	Classrooms (ages 9 plus)	1	812	21	10	0.12	35	210	97	307	307	307	714	242	242	(65)	No	97	low	
UV	513	Classrooms (ages 9 plus)	1	754	21	10	0.12	35	210	90	300	300	300	0	0	-	(300)	No	90	Unit not operable	
UV	514	Classrooms (ages 9 plus)	1	783	20	10	0.12	35	200	94	294	294	294	1024	480	480	186	Yes	94	Med	
UV	508	Classrooms (ages 9 plus)	1	725	18	10	0.12	35	180	87	267	267	267	902	230	230	(37)	No	87	Low	
UV	507	Classrooms (ages 9 plus)	1	798	22	10	0.12	35	220	96	316	316	316	707	265	265	(51)	No	96	Low	
UV	635	Classrooms (ages 5 to 8)	1	1071	27	10	0.12	25	270	129	399	399	399	1091	908	908	509	Yes	129	low	
UV	638	Classrooms (ages 5 to 8)	1	1071	26	10	0.12	25	260	129	389	389	389	652	0	-	(389)	No	129	low	
UV	642	Classrooms (ages 5 to 8)	1	1071	20	10	0.12	25	200	129	329	329	329	460	0	-	(329)	No	129	low	

			Filters (1 = clean, 2 = partially loaded, 3 = dirty)				TAB Measured					
Tag	AREA SERVED	Type	Pre-Filter Condition	Final Filter Conditon	Unit Condition	CO2 Control?	Supply Airflow2	Min. Outside Airflow2	% OA	Summated OA Airflow	MIN-OAD (CFM)	MAX-OAD (CFM)
RTU-1	New Gym	Single Zone Constant Volume	3	3	Fair	Yes	5,667	0	0%	2,474	412	2,480
RTU-2	New Stage	Single Zone Constant Volume	1	1	Poor	Yes	N/A	N/A	N/A	630	90	630
RTU-3	Cafeteria	Single Zone Constant Volume	3	3	Fair	Yes	2,209	306	14%	2,740	942	2,740
RTU-4	Art Room	Single Zone Constant Volume	3	3	Poor	Yes	1,981	249	13%	859	329	860
RTU-5	Admin	Multizone Variable Volume	2	2	Fair	Yes	3,159	416	13%	519	204	520
RTU-6	Media	Single Zone Constant Volume	3	3	Fair	Yes	4,380	530	12%	1,222	512	1,230
RTU-7	Computer Lab	Single Zone Constant Volume	2	2	Fair	Yes	1,249	171	14%	328	93	330
RTU-8	Reading	Single Zone Constant Volume	2	2	Fair	Yes	975	218	22%	394	179	400
AC-3	Nurse	Single Zone Constant Volume	3	3	Fair	No	929	-	0%	316	136	320
AHU-2	Gymnasium	Single Zone Constant Volume	2	2	Fair	Yes	4,958	1,018	21%	490	115	490
AHU-3	Gymnasium	Single Zone Constant Volume	2	2	Fair	Yes	4,327	335	8%	490	115	490
AHU-4	Gymnasium	Single Zone Constant Volume	2	2	Fair	Yes	2,048	77	4%	490	115	490

Appendix B: International Mechanical Code Minimum Ventilation Rates (2021) per ASHRAE 62.1

Minimum Ventilation Rates in Breathing Zone		People Outdoor Air Rate *Rp*	Area Outdoor Air Rate *Ra*	Default Values (Occupant Density)	Air Class	OS (6.2.6.1.4)	Comments
Occupancy Classification	**Category**	**cfm/person**	**cfm/sf**	**#/1000sf**			
Educational Facilities	Art Classroom	10	0.18	20	2	No	
Educational Facilities	Classrooms (ages 5 to 8)	10	0.12	25	1	No	
Educational Facilities	Classrooms (ages 9 plus)	10	0.12	35	1	No	
Educational Facilities	Computer Lab	10	0.12	25	1	No	
Educational Facilities	Daycare Sickroom	10	0.18	25	3	No	
Educational Facilities	Daycare (through age 4)	10	0.18	25	2	No	
Educational Facilities	Auditoriums	5	0.06	150	0		
Educational Facilities	Lecture Classroom	7.5	0.06	65	1	Yes	*Per ASHRAE, lecture classrooms are spaces with low space generated emissions and hard surfaces. Little off gassing so reduced levels. Most standard classrooms will be lecture classroom type.*
Educational Facilities	Lecture hall (fixed seats)	7.5	0.06	150	1	Yes	*University style (see occupant density)*
Educational Facilities	Libraries	5	0.12	10	n/a	No	
Educational Facilities	Media Center	10	0.12	25	1	No	
Educational Facilities	Multiuse assembly	7.5	0.06	100	1	Yes	
Educational Facilities	Music/theater/dance	10	0.06	35	1	Yes	
Educational Facilities	Science laboratories	10	0.18	25	2	No	
Educational Facilities	University/college laboratories	10	0.18	25	2	No	
Educational Facilities	Sports locker rooms	0	-0.7	0	0	No	
Educational Facilities	Wood/metal shop	10	0.18	20	2	No	
Food and Beverage	Bars, cocktail lounges	7.5	0.18	100	2	No	
Food and Beverage	Cafeteria/fast-food dining	7.5	0.18	100	2	No	
Food and Beverage	Kitchen (cooking)	7.5	0.18	20	2	No	
Food and Beverage	Restaurant dining rooms	7.5	0.18	70	2	No	
Private Dwellings	Toilet rooms - private	0	0	0	0		
Offices	Conference rooms	5	0.06	50	1	Yes	
Offices	Main entry lobbies	5	0.06	10	1	Yes	
Offices	Office spaces	5	0.06	5	1	Yes	
Offices	Reception areas	5	0.06	30	1	Yes	
Offices	Telephone/data entry	5	0.06	60	1	Yes	
Public spaces	Corridors	0	0.06	0			
Public spaces	Shower room	0	0	0			
Public spaces	Toilet rooms - public	0	0	0			
Public Assembly Spaces	Auditorium seating area	5	0.06	150	1	Yes	
Public Assembly Spaces	Libraries	5	0.12	10	1	No	
Public Assembly Spaces	Toilet rooms - public	0	0	0			
Sports and Entertainment	Bowling alley (seating)	10	0.12	40	1	No	
Sports and Entertainment	Disco/dance floors	20	0.06	100	2	Yes	
Sports and Entertainment	Gambling casinos	7.5	0.18	120	1	No	
Sports and Entertainment	Game arcades	7.5	0.18	20	1	No	
Sports and Entertainment	Gym, sports arena (play area)	20	0.18	7	2	No	
Sports and Entertainment	Health club/aerobics room	20	0.06	40	2	No	
Sports and Entertainment	Health club/weight room	20	0.06	10	2	No	
Sports and Entertainment	Spectator areas	7.5	0.06	150	1	Yes	
Sports and Entertainment	Stages, studios	10	0.06	70	1	Yes	
Sports and Entertainment	Swimming (pool and deck)	0	0.48	0	2	No	

Minimum Exhaust Rates				
Occupancy Classification	**Category**	**CFM/fixture**	**CFM/SF**	**Comments**
Educational Facilities	Toilet rooms - public	50	0	20
Educational Facilities	Toilet rooms - private	25	0	
Educational Facilities	Shower rooms	20	0	
Educational Facilities	Sports locker rooms	0	0.5	