Investigating Air Changes Per Hour: Outside Air, MERV, & HEPA - Does it Add Up?

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INTRINSIC
Environment, Health & Safety

Protecting People, Place & Planet

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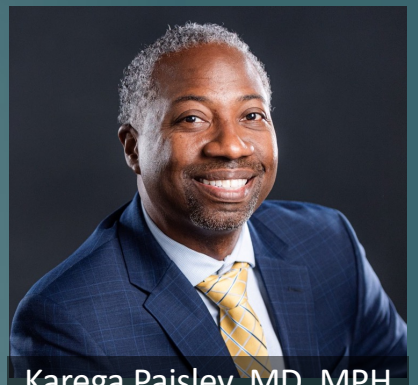
Stephanie W. Moore, MLA



Karega Paisley, MD, MPH

Nancy Gutierrez, MPH

Monique Miller MPH 2023

Amber Morris MPH 2023

Scientifically grounded solutions for complex occupational, environmental health challenges

THE WHITE HOUSE

BRIEFING ROOM

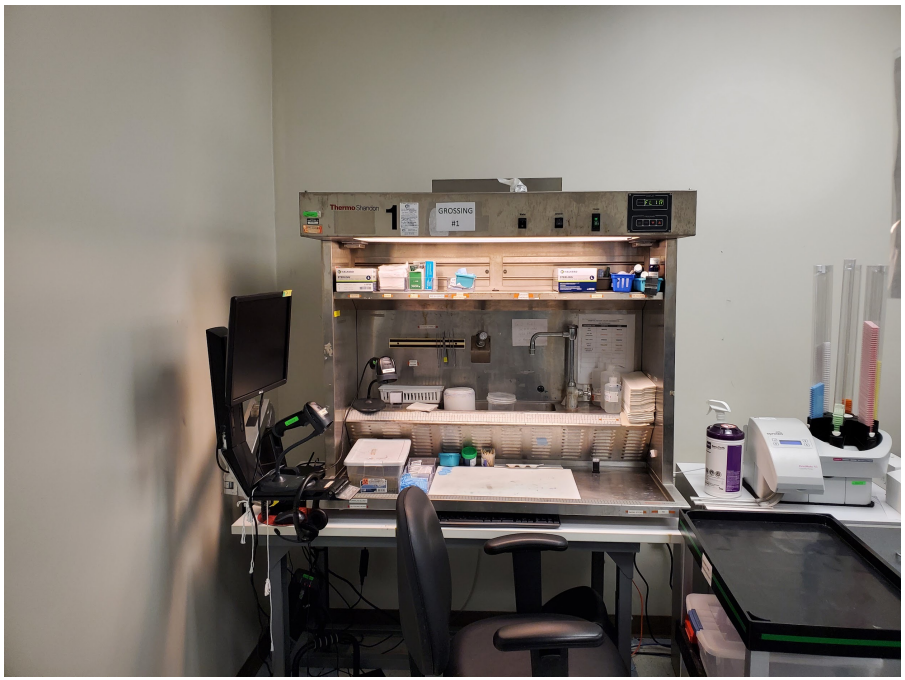
FACT SHEET: Biden Administration Launches Effort to Improve Ventilation and Reduce the Spread of COVID-19 in Buildings

MARCH 17, 2022 • STATEMENTS AND RELEASES


EACH


BIO-RAD
LAB


HCHO
1.19
LOW
ppm
ToxiRAE Pro
RAE


GROSSING


HYUNDAI

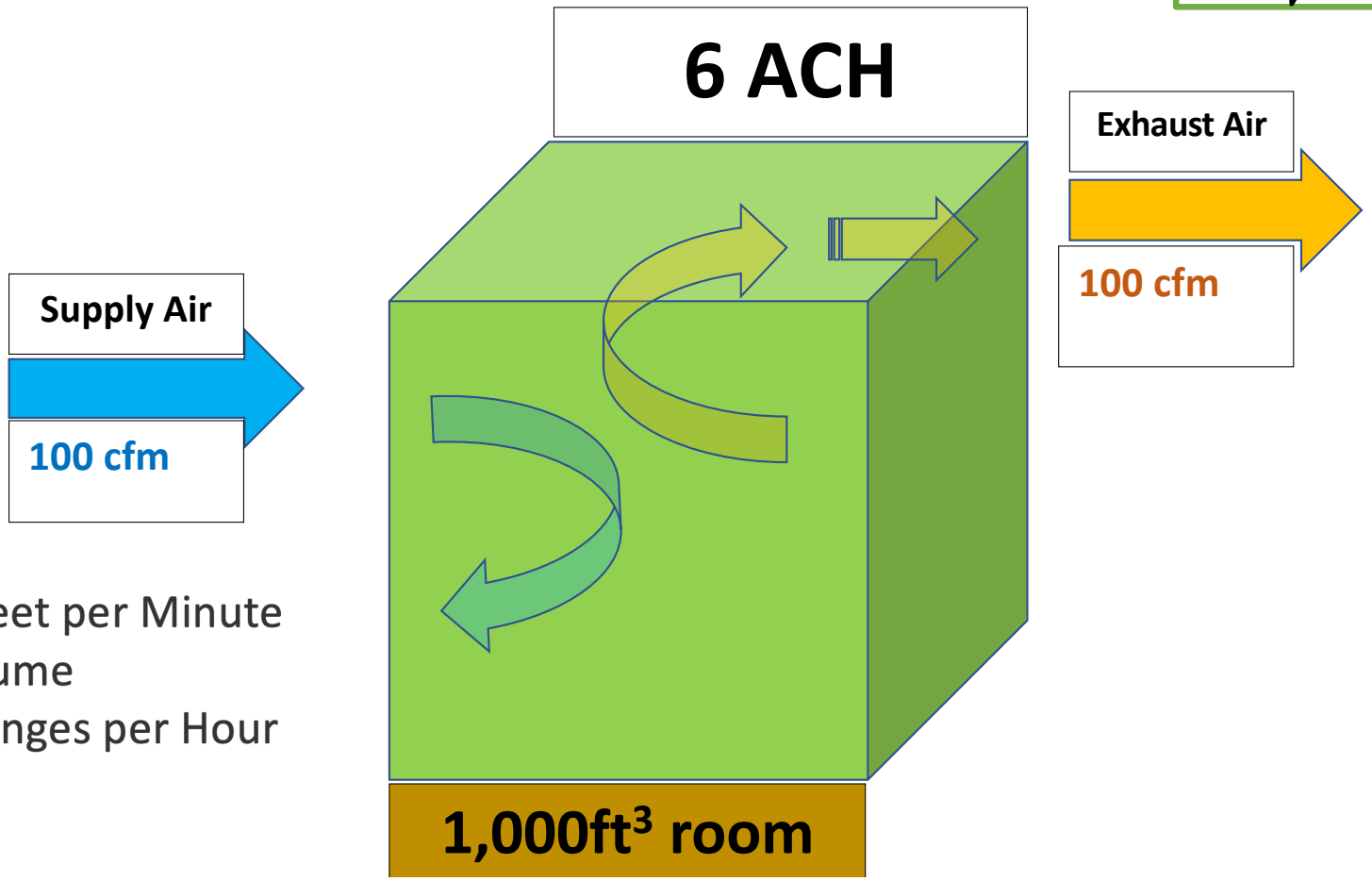
LEARNING OBJECTIVES

At the completion of this activity, the learner will be able to:

- Describe ACH, existing ASHRAE guidance, and implications for aerosol transmissible diseases and wildfire smoke mitigation
- Identify ventilation assessment methods to empirically measure the removal of airborne contaminants using outside air, MERV filtered air, and HEPA filtration individually, and in combination
- Summarize findings from a Bay Area classroom ACH study comparing the decay of carbon dioxide and PM 2.5 to estimates from direct airflow readings

Air Changes per Hour (ACH)

$$\frac{(cfm * 60)}{V} = \text{ACH}$$



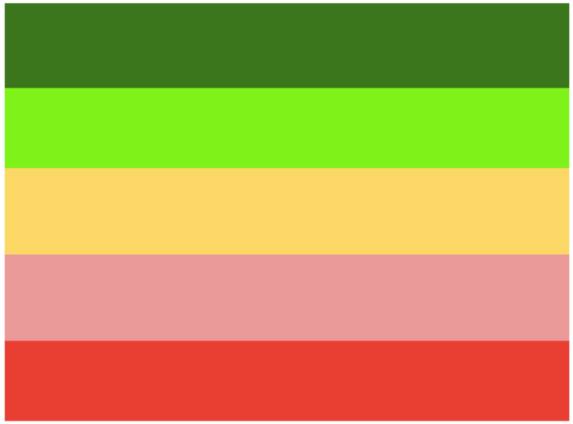
cfm = Cubic Feet per Minute
V = Room Volume
ACH = Air Changes per Hour


EXIT
MECHANICAL ROOM
DO NOT BLOCK DOOR


https://www.youtube.com/watch?v=cagRuiyAsio

HEALTHY BUILDINGS FOR HEALTH
HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

TARGET IS AT LEAST 5 TOTAL AIR CHANGES PER HOUR



Ideal (6 ACH)

Excellent (5-6 ACH)

Good (4-5 ACH)

Bare minimum (3-4)

Low (<3 ACH)

https://schools.forhealth.org/wp-content/uploads/sites/19/2021/01/Harvard-Healthy-Buildings-program-How-to-assess-classroom-ventilation-10-30-2020-EN_R1.8.pdf

ASHRAE EPIDEMIC TASK FORCE

BUILDING READINESS | Updated 5-17-2022

General Information
- Building Readiness Intent
- Building Readiness Team
- Building Readiness Plan

Epidemic Conditions in Place (ECiP)
- Systems Evaluation
- Building Automation Systems (BAS)
- Ventilation per Code / Design
- Increased Ventilation above Code
- Increased Ventilation Control
- Building and Space Pressure
- Flushing Between Occupied Periods
- Equivalent Outdoor Air
- Upgrading and Improving Filtration
- Filter Droplet Nuclei Efficiency / Particle Size Expectations
- Energy Savings Considerations
- Exhaust Air Re-entrainment
- Energy Recovery Ventilation Systems Operation Considerations
- UVGI Systems
- Domestic Water & Plumbing Systems
- Maintenance Checks

Post-Epidemic Conditions in Place (P-ECiP)
- P-ECiP: Prior to Occupying
- P-ECiP: Operational Considerations once Occupied
- P-ECiP: Ventilation
- P-ECiP: Filtration
- P-ECiP: Building Maintenance Program
- P-ECiP: Systems Manual

Additional Information
- Acknowledgements
- References
- Disclaimer

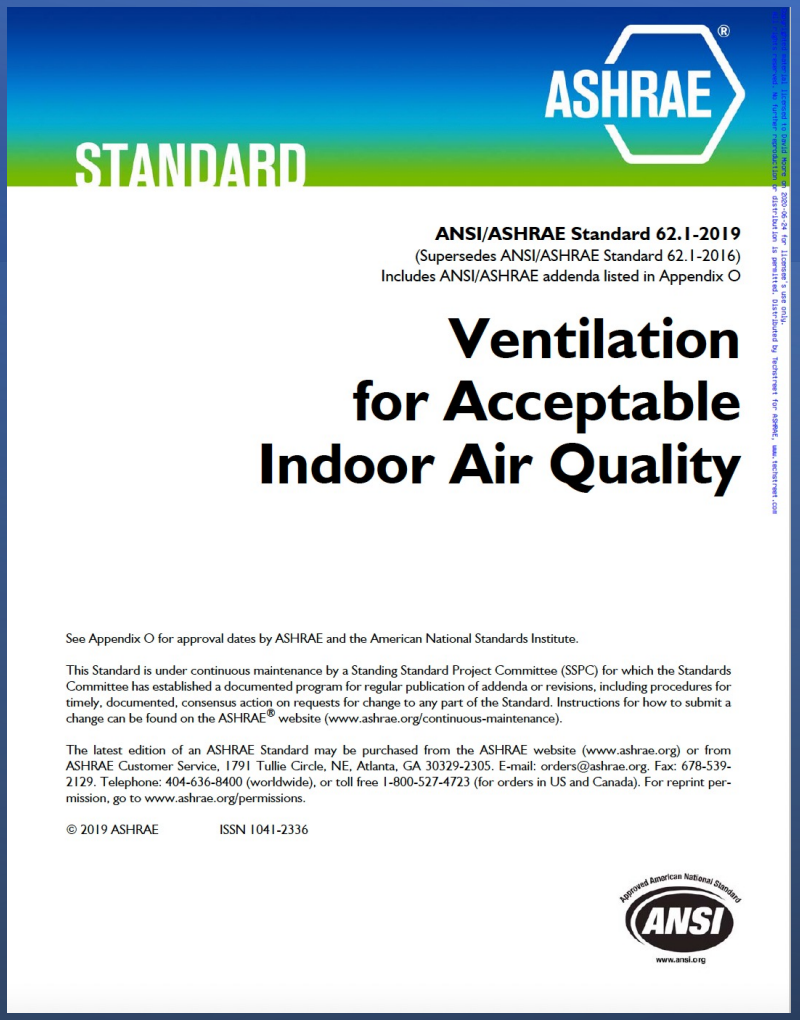
https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

Name of Space / AHU / Building	Units	MERV 13	MERV-8 and UVGI	MERV-8 and IR	MERV-11 and UVGI	Lecture - Max	Lecture - Min
Area	Sq Ft	900	900	900	900	780	780
Average Ceiling Height	Ft	9	9	9	9	11	11
Volume	Cu Ft	8100	8100	8100	8100	8580	8580
Total Supply Air	CFM	1350	1350	1350	1350	1920	480
Total Outdoor Air	CFM	337.5	337.5	337.5	337.5	460.8	480
Supply Air ACH	ACH	10.00	10.00	10.00	10.00	13.43	3.36
Outdoor Air ACH	ACH	2.50	2.50	2.50	2.50	3.22	3.36
Central AHU Filter MERV Rating	MERV	8	11	8	11	13	13
UVC Single Pass Inactivation	%	0.00%	80.00%	0.00%	80.00%	0.00%	0.00%
In Room Fan HEPA Filter	CADR	0	0	200	0	0	0
Number of In Room Fan HEPA Filters	Qty	0	0	2	0	1	0
Effective Air Changes Based on Technology							
ACH_OA	ACH	2.5	2.5	2.5	2.5	3.2	3.4
ACH_filter (in AHU)	ACH	3.7	5.0	3.7	5.0	8.8	0.0
ACH_e,c	ACH	0.0	2.0	0.0	2.0	0.0	0.0
ACH_air cleaner	ACH	0.0	0.0	3.0	0.0	0.0	0.0
Sub-Total Effective ACH	ACH	6.2	9.5	9.1	9.5	12.0	3.4
Total Effective ACH_e		4.3	6.7	7.3	6.7	8.4	2.3
Time Required to achieve Target Air Change	Target Air Changes	3	3	3	3	3	3
Minutes	Min	41.6	27.1	28.1	27.1	21.4	76.6
Hours	Hours	0.69	0.45	0.47	0.45	0.36	1.28

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

HARVARD - CU BOULDER PORTABLE AIR CLEANER CALCULATOR FOR SCHOOLS.v1		
AUTHORS	Joseph Allen	Healthy Buildings Program, Harvard T.H. Chan School of Public Heatlh
	Jose Cedeno-Laurent	Healthy Buildings Program, Harvard T.H. Chan School of Public Health
	Shelly Miller	Mechanical Engineering, College of Engineering and Applied Science, University of Colorado Boulder
ABOUT	This tool supports the Harvard 'Schools for Health' report on risk reduction strategies for schools and should not be used in isolation	
	Link to full report: https://schools.forhealth.org/risk-reduction-strategies-for-reopening-schools/	
	This guidance does not supercede guidance from CDC, WHO, state and local guidance, or other bodies	
	It is provided to support efforts to supplement outside air ventilation with air cleaning using well established particle filtration strategies	
	To input values from your indoor spaces of interest, download the calculator as .xlsx file.	
DATE	November 8, 20	
VERSION	v1.3	
LINK TO FILE	https://docs.google.com/spreadsheets/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/edit#gid=0	
SHORT URL	https://tinyurl.com/portableaircleanertool	
	check back often for updates!	
IMPORTANT	This tool is intended to simplify decision-making around portable air cleaners in schools for airborne transmission control (it can also be applied to residential or office air cleaning, noting differences in ventilati	
	Airborne transmission is not the only mode of transmission, therefore additional risk reduction strategies are required	
	UNIVERSAL MASK WEARING SHOULD BE REQUIRED AND SOCIAL DISTANCING MORE THAN 6 FEET (~2 meters) IS EMPHASIZEI	
	Read the DISCLAIMER at bottom of this workshee	
	Schools should open when community spread is controlled and this guidance should come from the local public health officials	
	For information on when to open based on community spread: https://globalhealth.harvard.edu/path-to-zero-schools-achieving-pandemic-resilient-teaching-and-learning-spaces/	
NOTES		
	Quick 'rule of thumb' selection guide for portable air cleaners	
	Look for portable air purifier with HEPA filter	
	Look for high clean air delivery rate	
	Avoid add-ons (e.g., ionizers, ultraviolet lights)	
	Placement of the device matters	
	The calculations are based on a simple-box model that assumes equal-mixing in a room	
	Avoid having air blow across individuals	

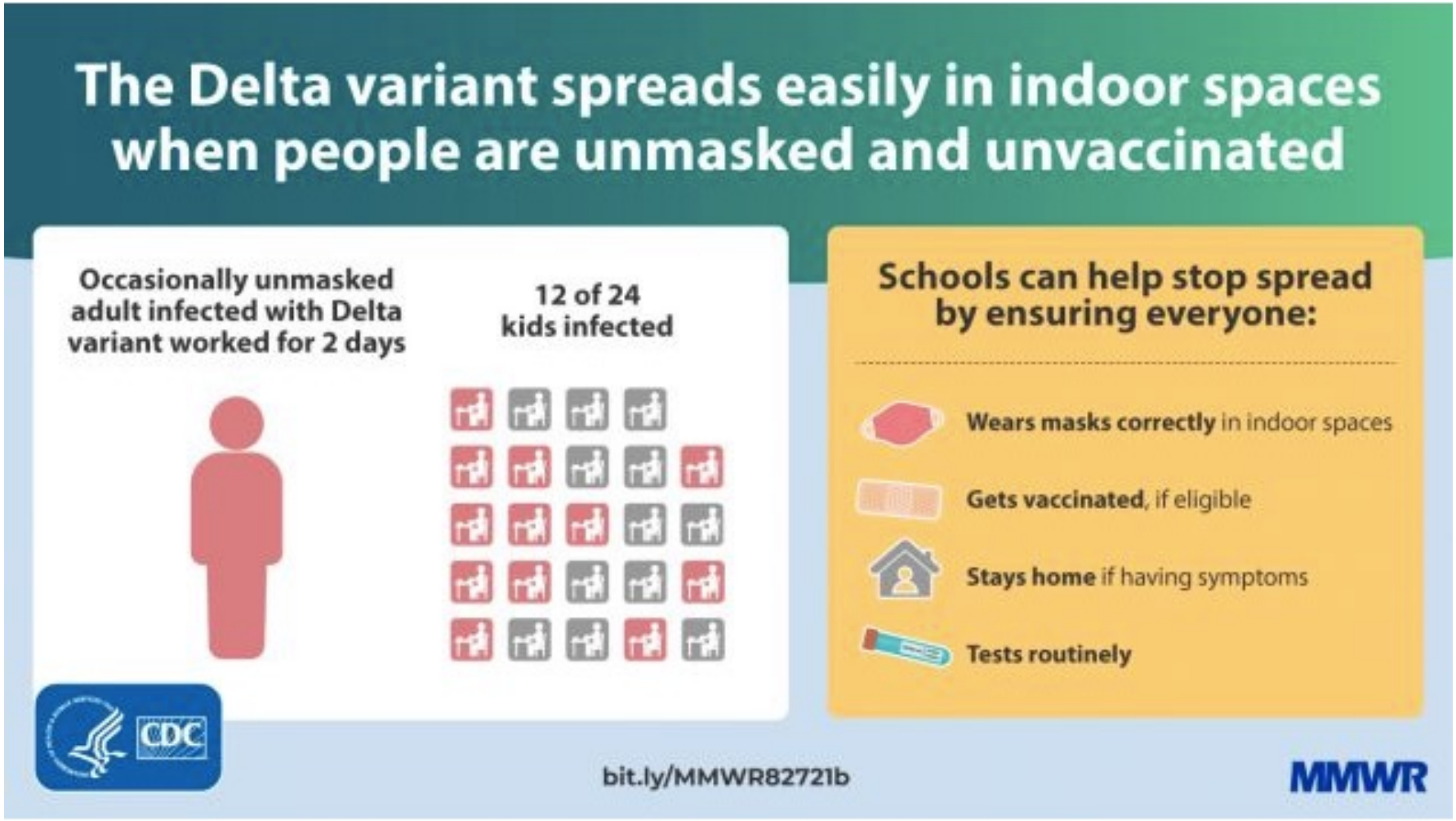
https://docs.google.com/spreadsheets/u/1/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/htmlview?pru=AAABdJy-keg*h6HfWPe6IhFSVAy53UNvDw



https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2

ASHRAE				
		cfm/person	cfm/sq ft	Default occupancy (per 1000 sq ft)
Classrooms	5-8 year olds	10	0.12	25

https://docs.google.com/spreadsheets/u/1/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/htmlview?pru=AAABdJy-keg*h6HfWPe6IhFSVAy53UNvDw



https://www.cdc.gov/mmwr/volumes/70/wr/mm7035e2.html

ASHRAE				
		cfm/person	cfm/sq ft	Default occupancy (per 1000 sq ft)
Classrooms	5-8 year olds	10	0.12	25

https://docs.google.com/spreadsheets/u/1/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/htmlview?pru=AAABdJy-keg*h6HfWPe6IhFSVAy53UNvDw

$$\frac{(cfm * 60)}{V} = \text{ACH}$$

1000	sqft room*	
cfm	cfm/person	**ACH**
370.0	14.8	**2.8**
*assumes 8 foot ceiling		

$$\frac{(cfm * 60)}{V} = \text{ACH}$$

$$\frac{(370 * 60min)}{8ft * 1{,}000sq\ ft} = 2.8\ \text{ACH}$$

ASHRAE				
		cfm/person	cfm/sq ft	Default occupancy (per 1000 sq ft)
Classrooms	5-8 year olds	10	0.12	25

1000	sqft room*	
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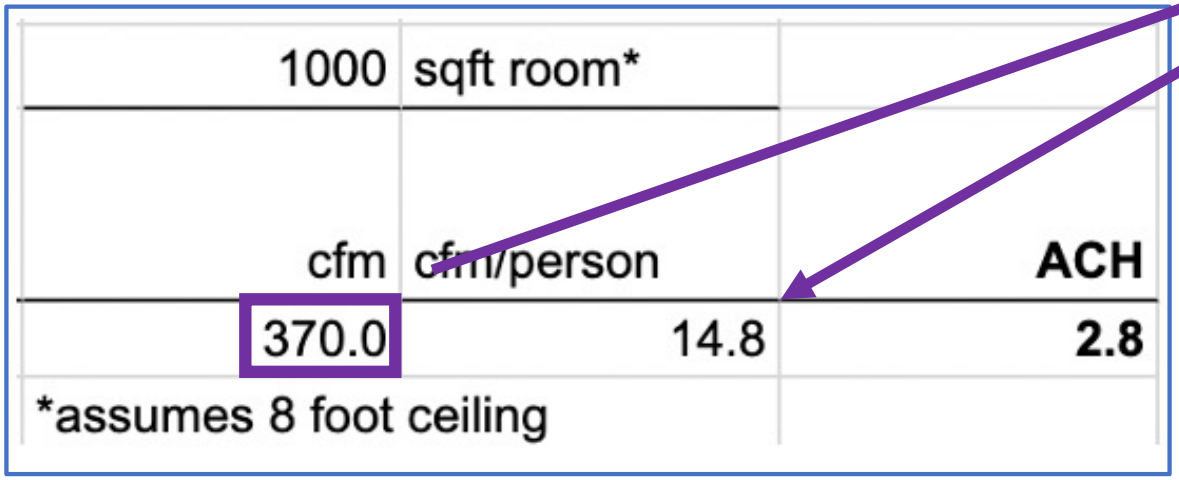
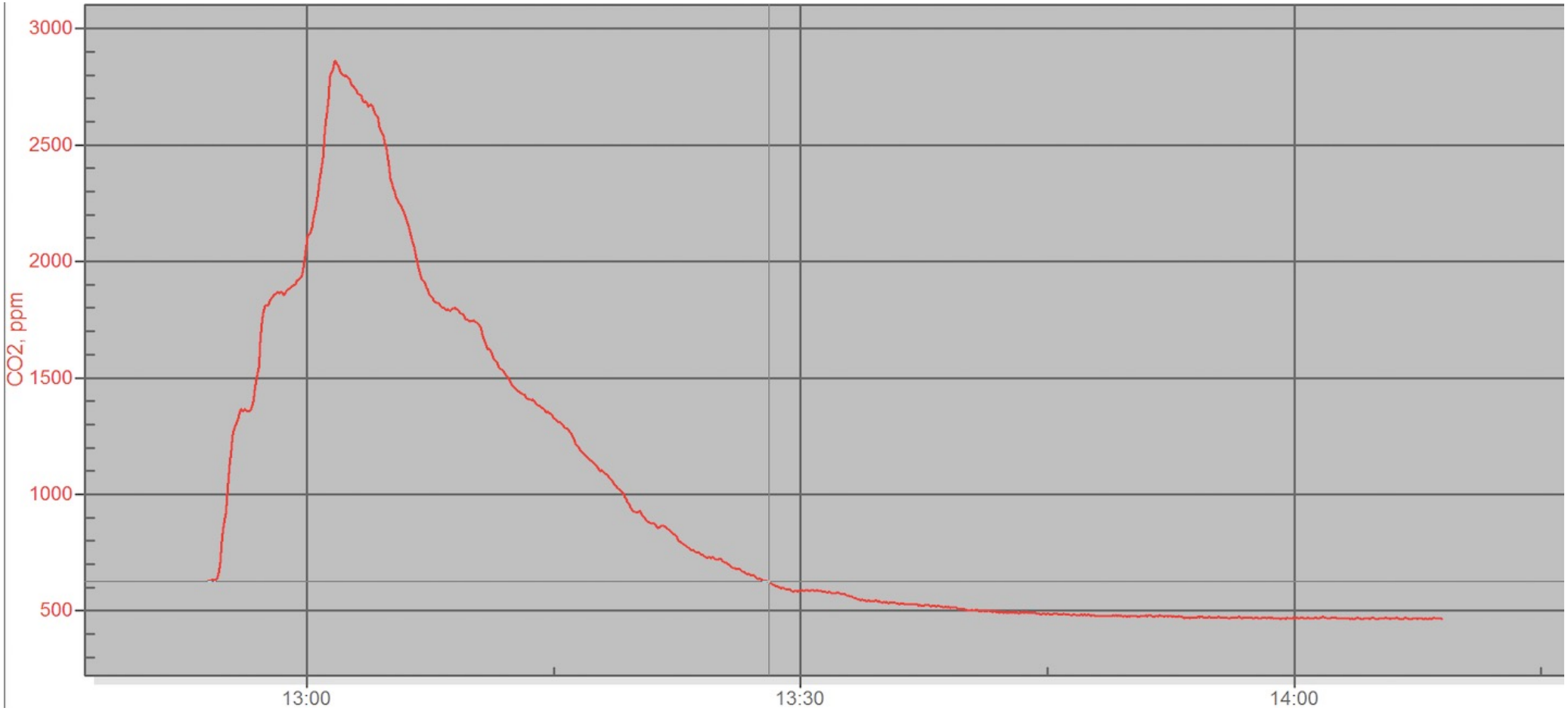


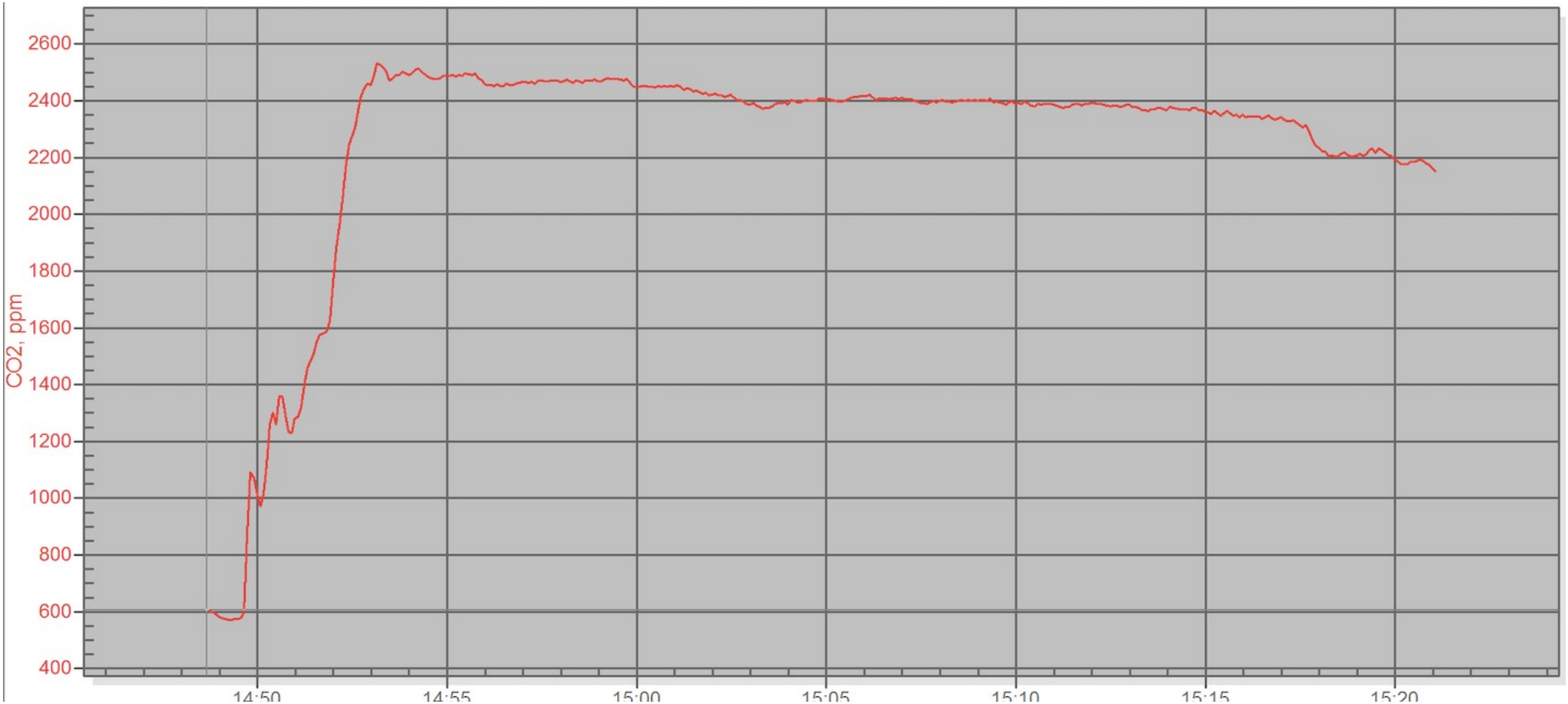
CO_2 CONCENTRATION IN ROOM WITH WINDOWS OPEN

~2.5 ACH (Air Changes/Hour)



CO2 Concentration in Room with no HVAC, No Windows

~0.4 ACH (Air Changes/Hour)



Clinical Infectious Diseases

MAJOR ARTICLE

Effectiveness of 3 Versus 6 ft of Physical Distancing for Controlling Spread of Coronavirus Disease 2019 Among Primary and Secondary Students and Staff: A Retrospective, Statewide Cohort Study

Polly van den Berg,[1] Elissa M. Schechter-Perkins,[2] Rebecca S. Jack,[3] Isabella Epshtein,[4] Richard Nelson,[5,6] Emily Oster,[3,7] and Westyn Branch-Elliman[4,8,9]

https://academic.oup.com/cid/advance-article/doi/10.1093/cid/ciab230/6167856?searchresult=1

They found!

"Student case rates were similar in the 242 districts with ≥3 versus ≥6 ft of physical distancing between students"

"Cases among school staff in districts with ≥3 versus ≥6 ft of physical distancing were also similar"

"Ventilation interventions were highly heterogeneous…"

Ventilation Interventions in MA Cohort Study

- Opening windows
- HEPA filters
- HVAC upgrades
- Classrooms moved outdoors

Epidemic Conditions in Place

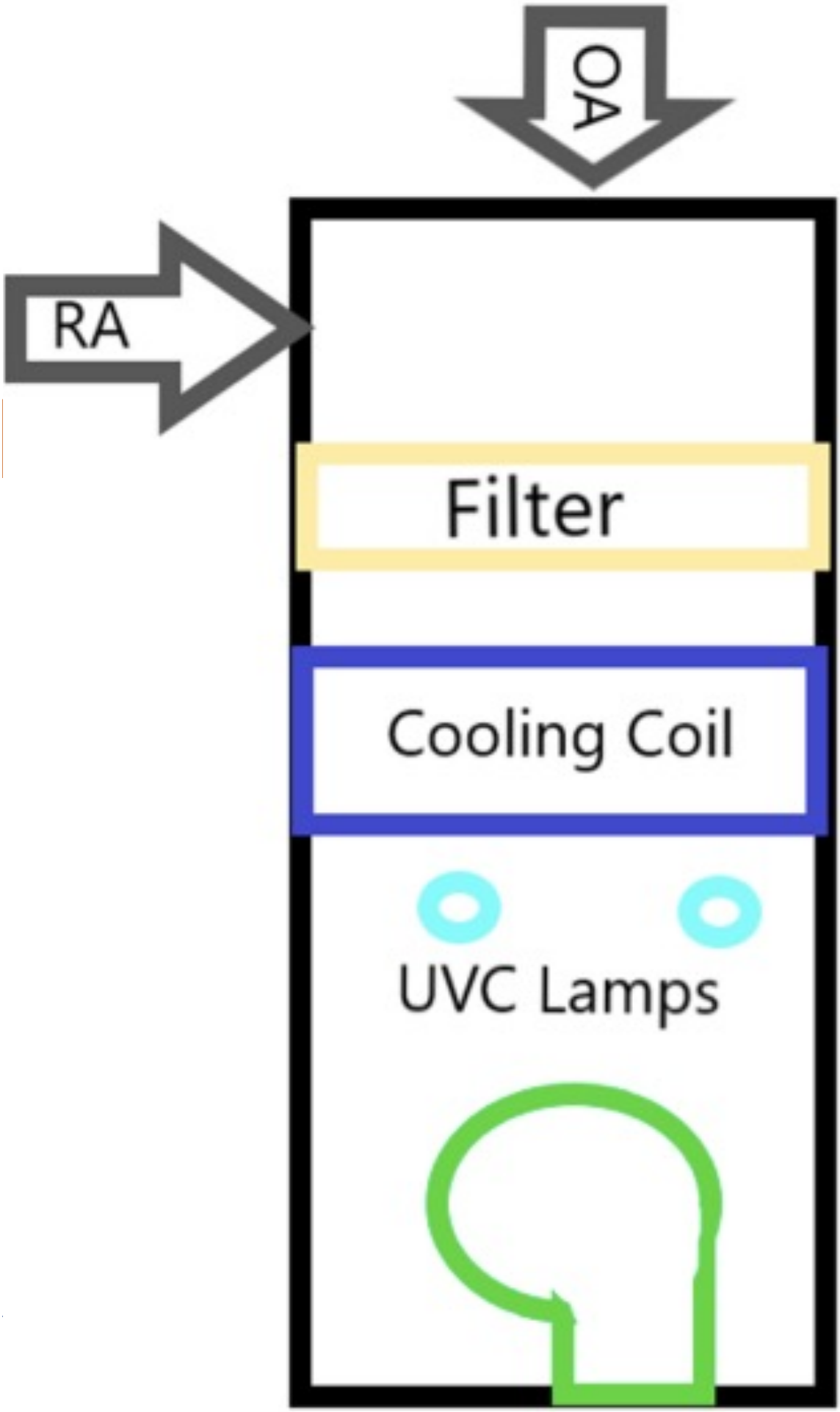
Equivalent Outdoor Air Continued:

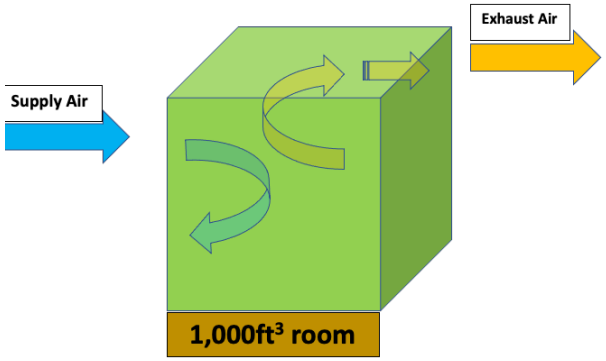
Assumptions:

Q_R is the recirculated air
ACH_e is the air changes of equivalent outdoor air
ACH_oa is the air changes of outdoor air
ACH_f is the equivalent outdoor air changes due to filtration (assumed new filters that are well installed)
ACH _e,c is the equivalent outdoor air changes due to the air cleaner after the effect of the filter

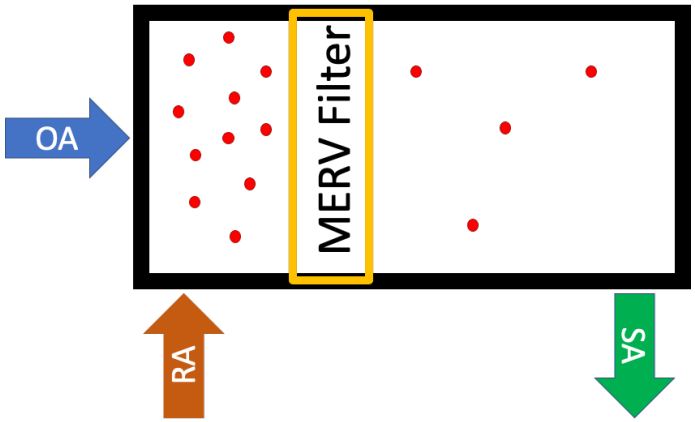
Q_R is the recirculated air
Q-e is the equivalent outdoor air flow rate
Q-e,f is the equivalent outdoor air flow rate from the filter
Q-e,f+c is the equivalent outdoor air flow rate from the air cleaner (after it went across the filter)
E_z = zone air distribution effectiveness (From Std 62.1 Table 6-4)
eta_f is the efficiency of filter
eta_c is the efficiency of the air cleaner
eta_T is the total efficiency of the series of devices

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf


OA
RA
Filter
Cooling Coil
UVC Lamps



$$\frac{(cfm * 60)}{V} = \text{ACH}$$



$$\frac{([cfm\ OA + cfm\ RA * MERV\% + cfm\ HEPA] * 60\ \text{min})}{V} = \text{ACH}$$

cfm = cubic feet per minute

ACH = Air Changes per Hour

MERV = Minimum Efficiency Reporting Value

OA = Outside Air

RA = Return Air

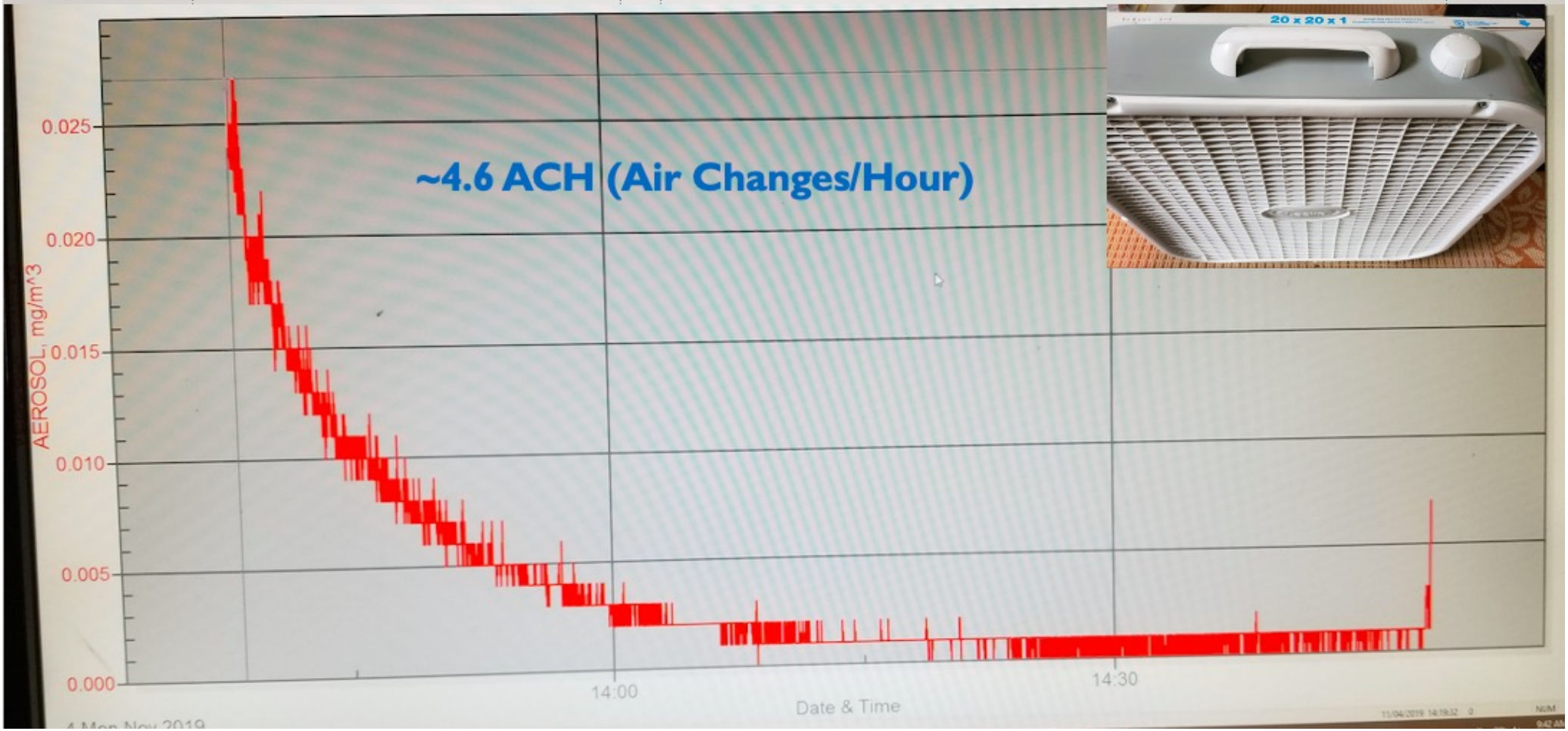
SA = Supply Air

$$\textit{TOTAL SA} = cfm\ OA + cfm\ RA$$

Source: Central Coast Alliance United for a Sustainable Economy

Agricultural workers face wildfire smoke in Sonoma County - IG post

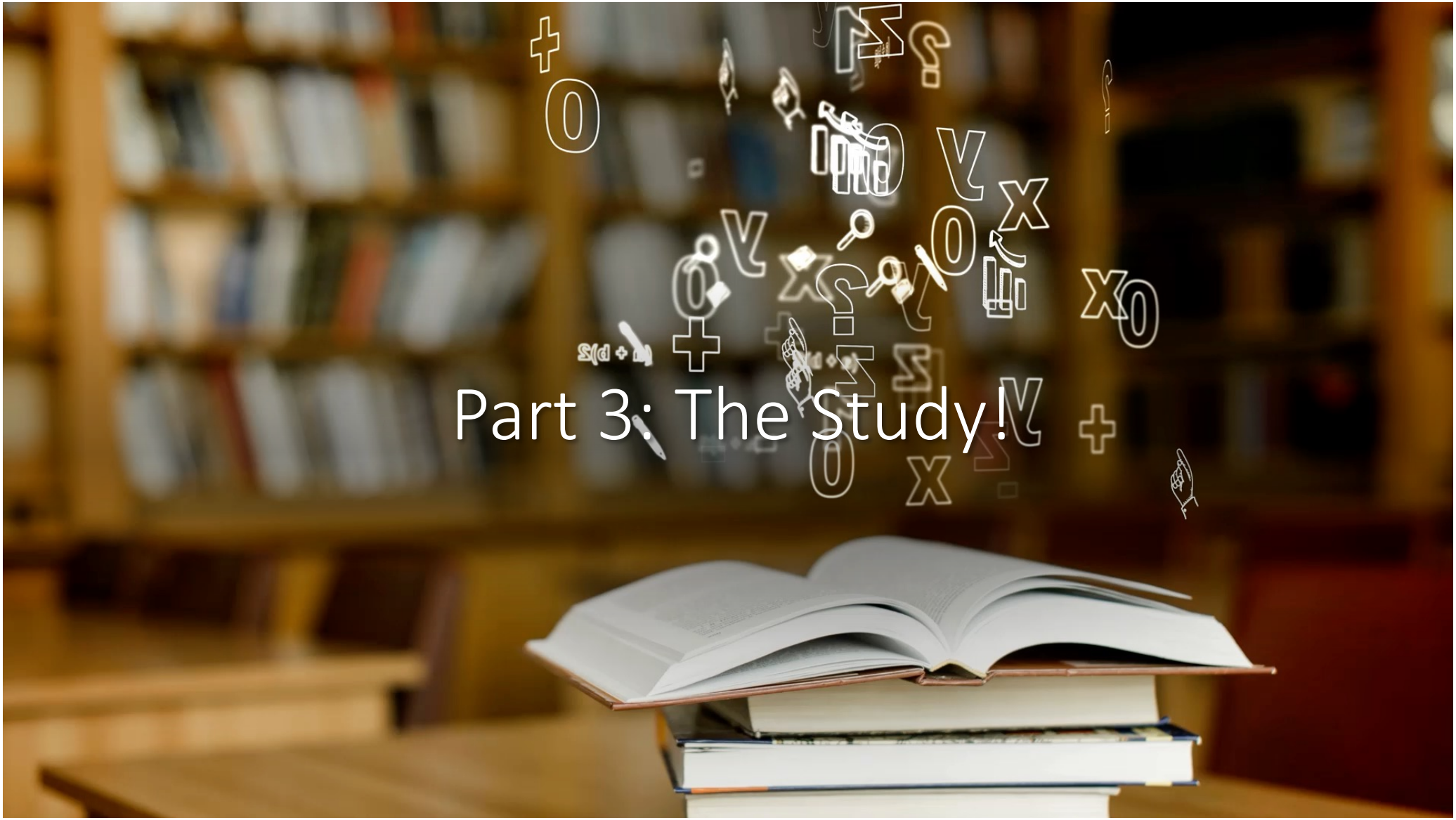
MERV 13 DIY Box Fan Filter running in small bedroom during wildfire season (PM 2.5)



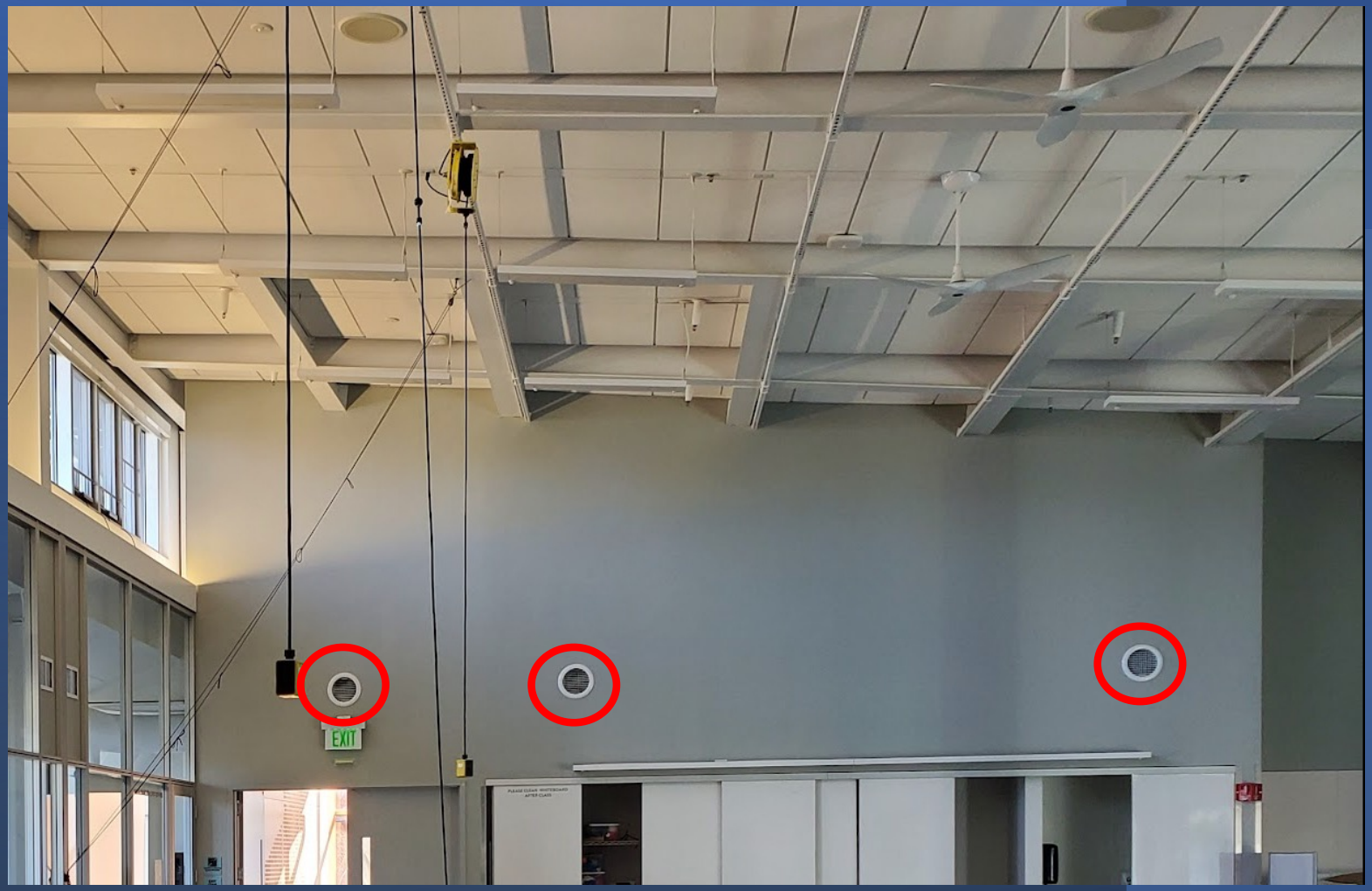
MERV Rating (Based on 52.2-2017)	E1 (%)	E2 (%)	E3 (%)
4	10.3	29.9	11.9
5	8.0	28.0	33.0
6	7.8	30.0	43.5
7	10.8	36.6	55.6
8	15.1	51.6	73.7
9	17.8	52.4	84.8
10	16.6	59.0	86.7
11	33.9	69.4	90.1
12	37.6	86.1	99.8
13	66.3	92.4	97.8
14	81.4	96.6	99.3
15	86.4	97.8	99.1
16	95.0	98.0	98.0

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

MERV	(µm) PSE (%)	0.30-1.0	1.0-3.0	3.0-10
13		62	87	95


Part 3: The Study!

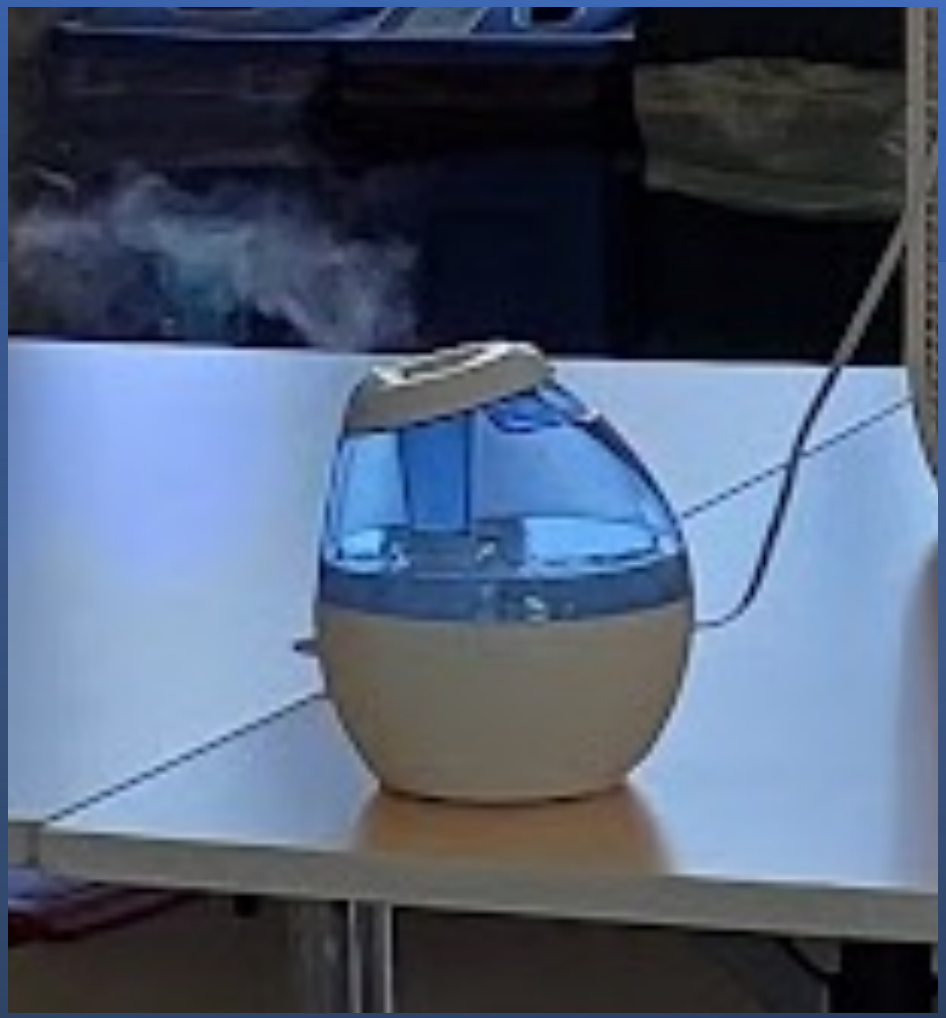

RHEE STUDIO


EXIT


TYLER FAMILY STUDIO
310 B

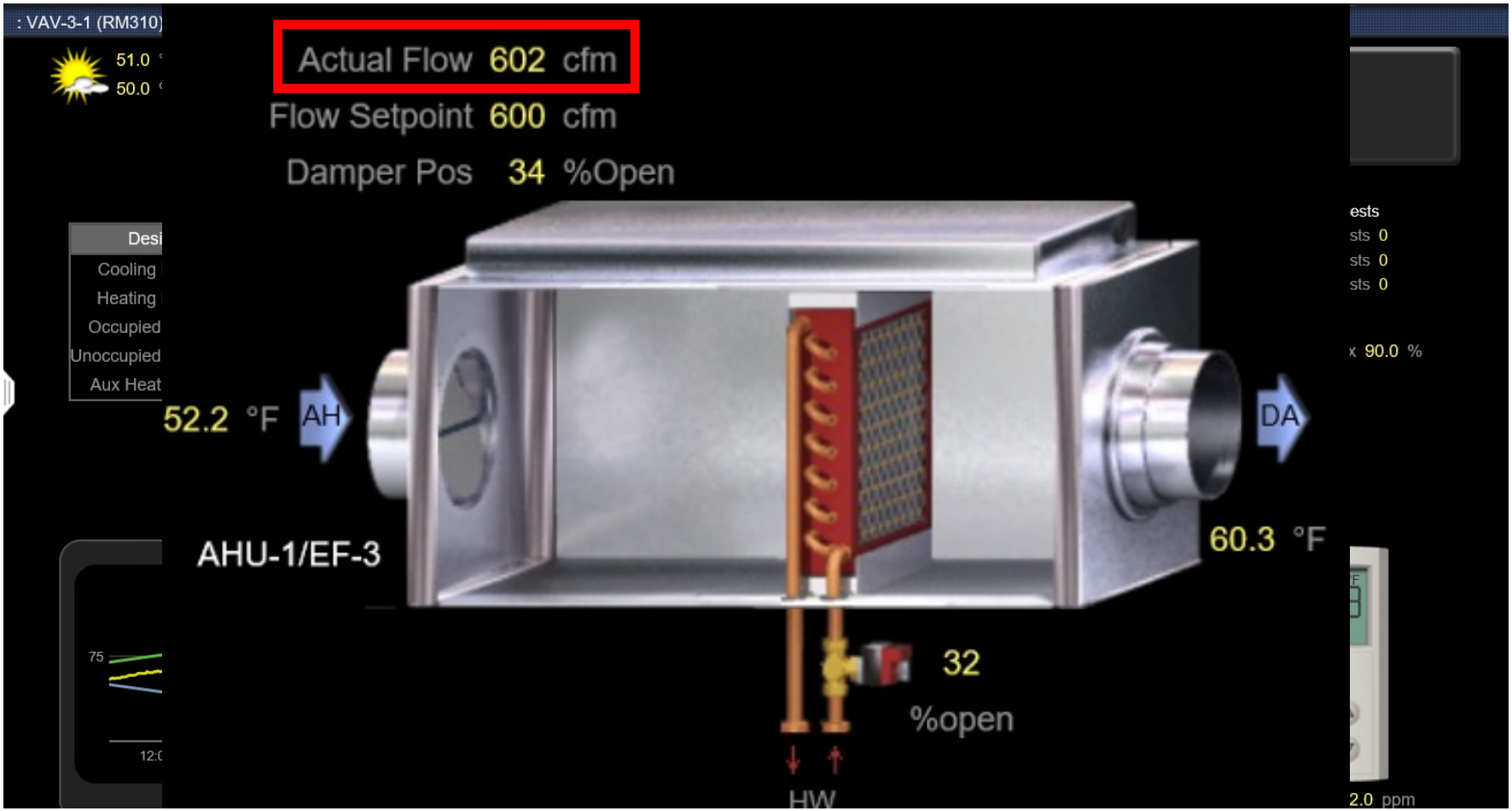

Portable Test
Aerosol Generator
Model 3073
Nozzle Pressure [hPa]
Link / Power
Set point / On

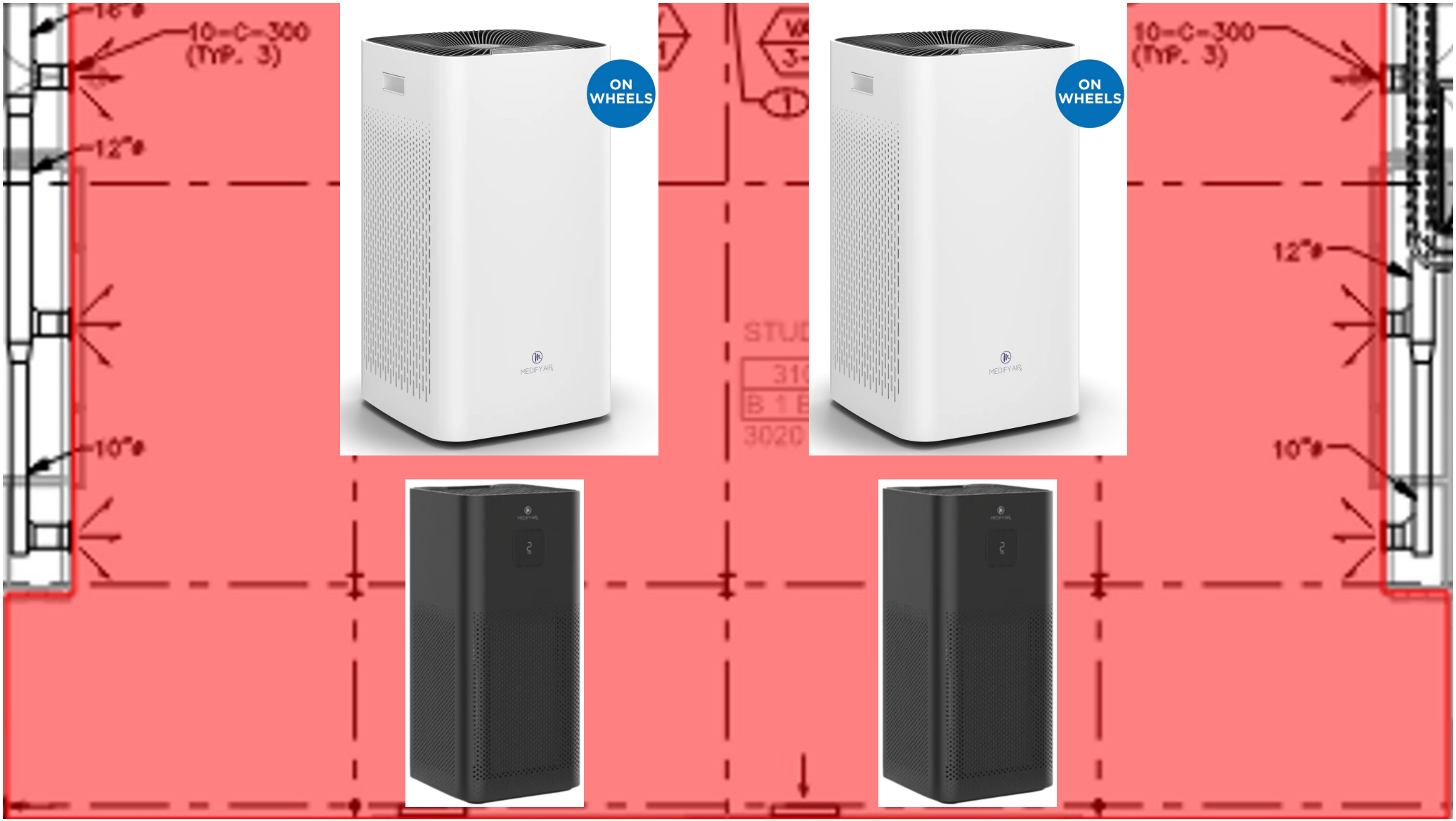

VICKS




NanoScan SMPS
Running
Statistics
Scan
Single
Setup
Main


RHEE STUDIO


: VAV-3-1 (RM310)
51.0
50.0
Actual Flow 602 cfm
Flow Setpoint 600 cfm
Damper Pos 34 %Open
Desi
Cooling
Heating
Occupied
Unoccupied
Aux Heat
52.2 °F
AH
DA
60.3 °F
AHU-1/EF-3
32
%open
HW
ests
sts 0
sts 0
sts 0
90.0 %
2.0 ppm
75
12:0


16"ø
10-C-300
(TYP. 3)
12"ø
10"ø
ON
WHEELS
MEDIFY AIR
ON
WHEELS
MEDIFY AIR
10-C-300
(TYP. 3)
12"ø
10"ø

20”x20”x1” MERV 13 filter

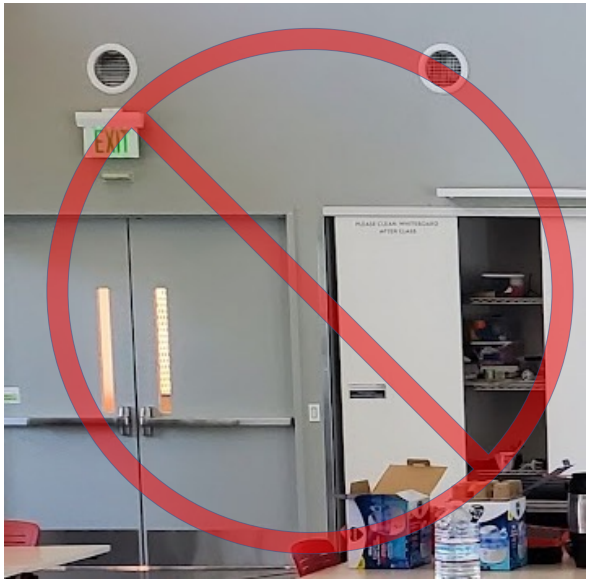
Custom plywood frame, fabricated in Jacobs Hall

Total air flow rate with filter and acoustic crystal installed ~ 410 cfm

Taylor Lab Bear Air Unit, 2021

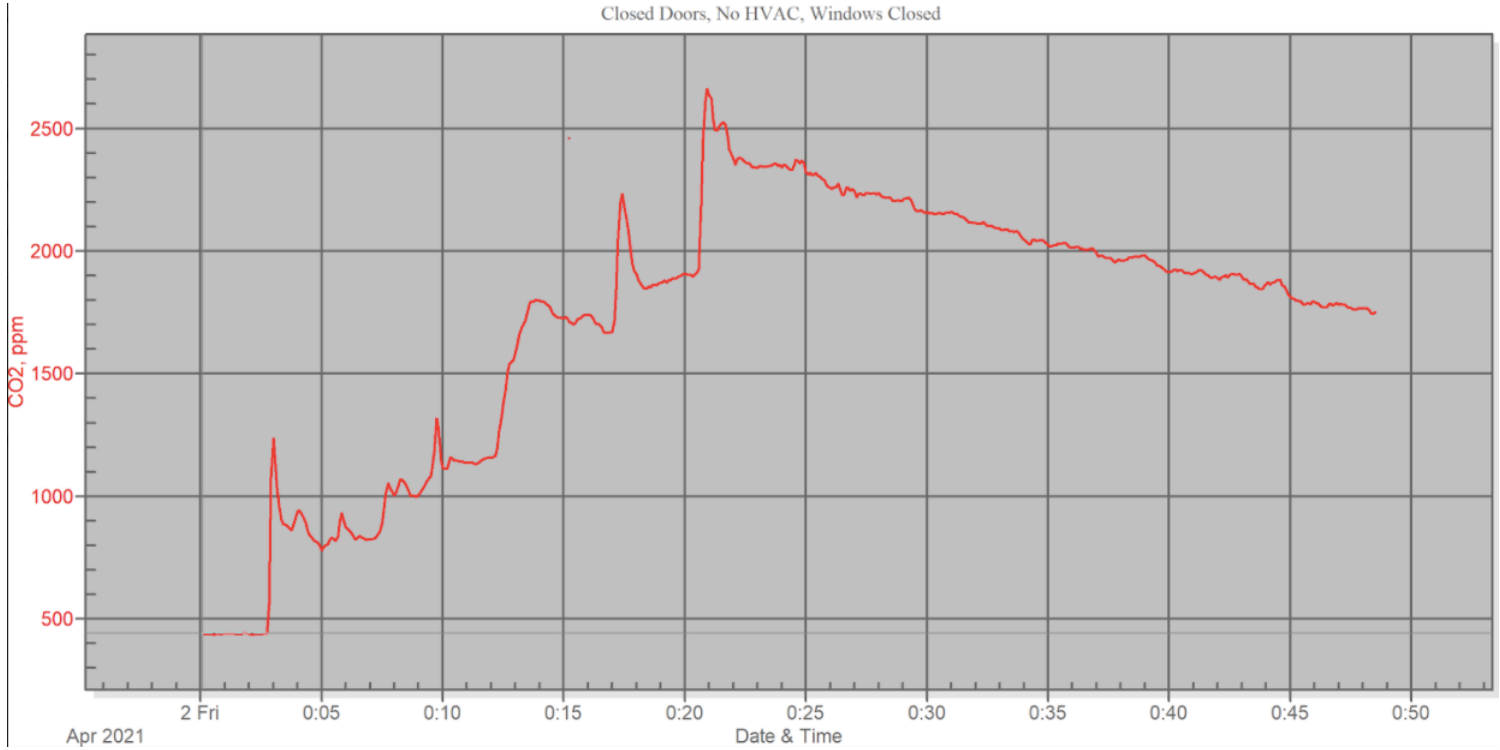
MERV: Minimum Efficiency Reporting Value


10-C-300
(TYP. 3)
12"
10"
ON
WHEELS
MEDIFY AIR
20 inches
10-C-300
(TYP. 3)
12"
10"
ON
WHEELS
MEDIFY AIR
20 inches

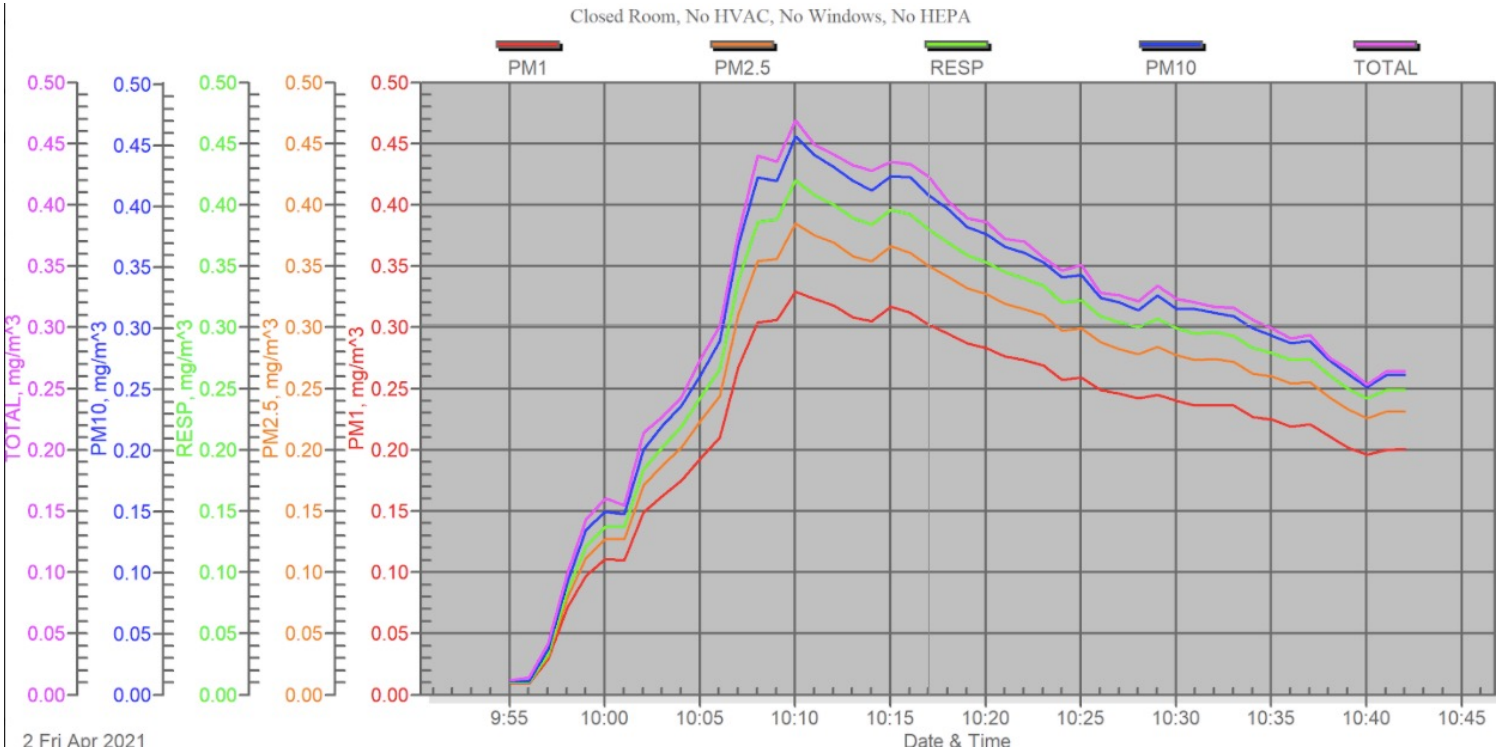


Baseline Test: Closed Room, No HEPA, No Windows

0.7 ACH


Closed Doors, No HVAC, Windows Closed
CO2, ppm
2500
2000
1500
1000
500
2 Fri
Apr 2021
0:05
0:10
0:15
0:20
0:25
0:30
0:35
0:40
0:45
0:50
Date & Time

0.8 ACH


Closed Room, No HVAC, No Windows, No HEPA
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
9:55
10:00
10:05
10:10
10:15
10:20
10:25
10:30
10:35
10:40
10:45
Date & Time
2 Fri Apr 2021

So How do you calculate ACH with CO_2 or $PM_{2.5}$ Decay?

- Question 1: How many Air Changes per Hour with Natural Ventilation?

- Do the math!!!

  C_1

  C_2

  t

$$ACH = [\ln(C_1/C_2)]*60/t$$

1. Airborne Contaminant Removal

$$ACH = [\ln(C1/C2)*60/t$$

Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *

ACH § ¶	Time (mins.) required for removal 99% efficiency	Time (mins.) required for removal 99.9% efficiency
2	138	207
4	69	104
6+	46	69
8	35	52
10+	28	41

$$t2 - t1 = - [\ln (C2 / C1) / (Q / V)] \times 60, \text{ with } t1 = 0$$

https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html

ACH = [ln(C1/C2)*60/t

For 99% Efficiency

C_1 = 100%

C_2 = 1%

ACH § ¶	Time (mins.) required for removal 99% efficiency
2	138

https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html

Calculating Exponential Decay with Phone Calculator

Android

Apple

Calculating Exponential Decay with Phone Calculator

Android

Apple

Calculating Exponential Decay with Phone Calculator

Android

Apple

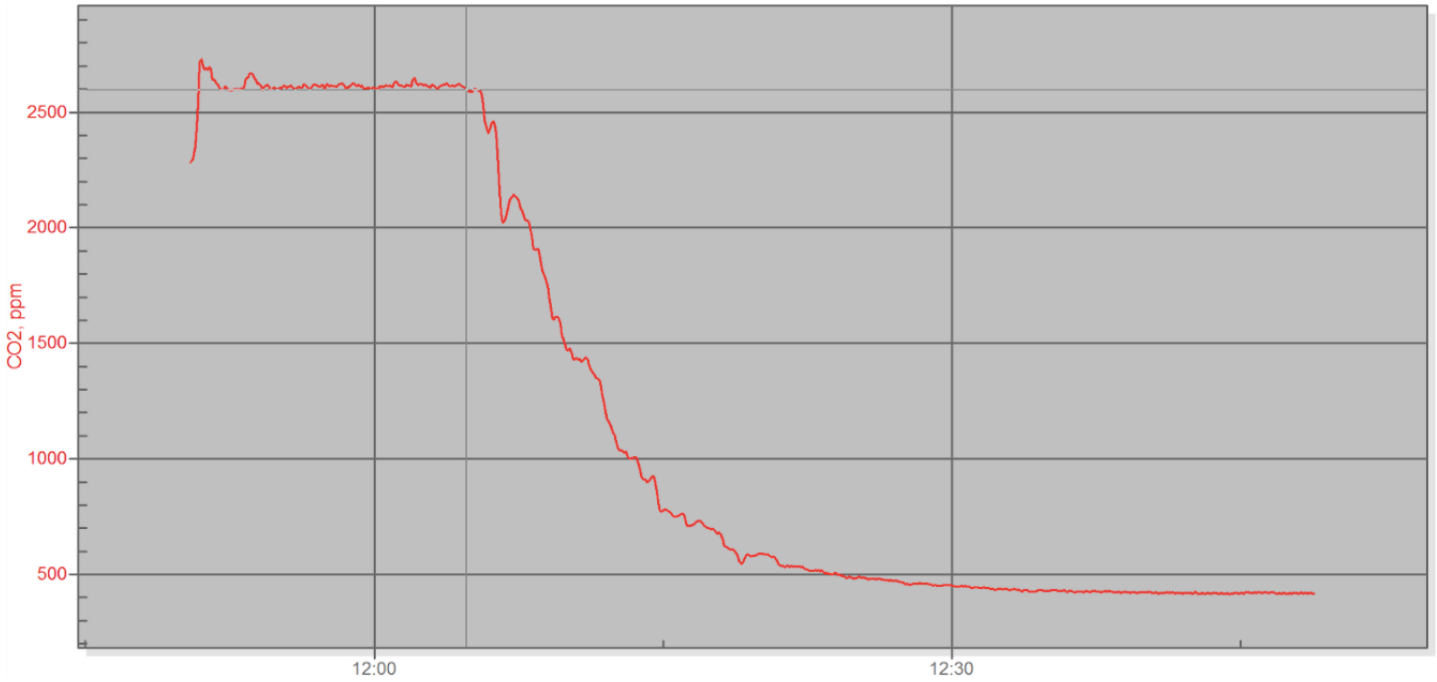
$$ACH = [\ln(C1/C2)]*60/t$$

For 99% Efficiency

$C_1 = 100\%$

$C_2 = 1\%$

ACH § ¶	Time (mins.) required for removal 99% efficiency
2	138

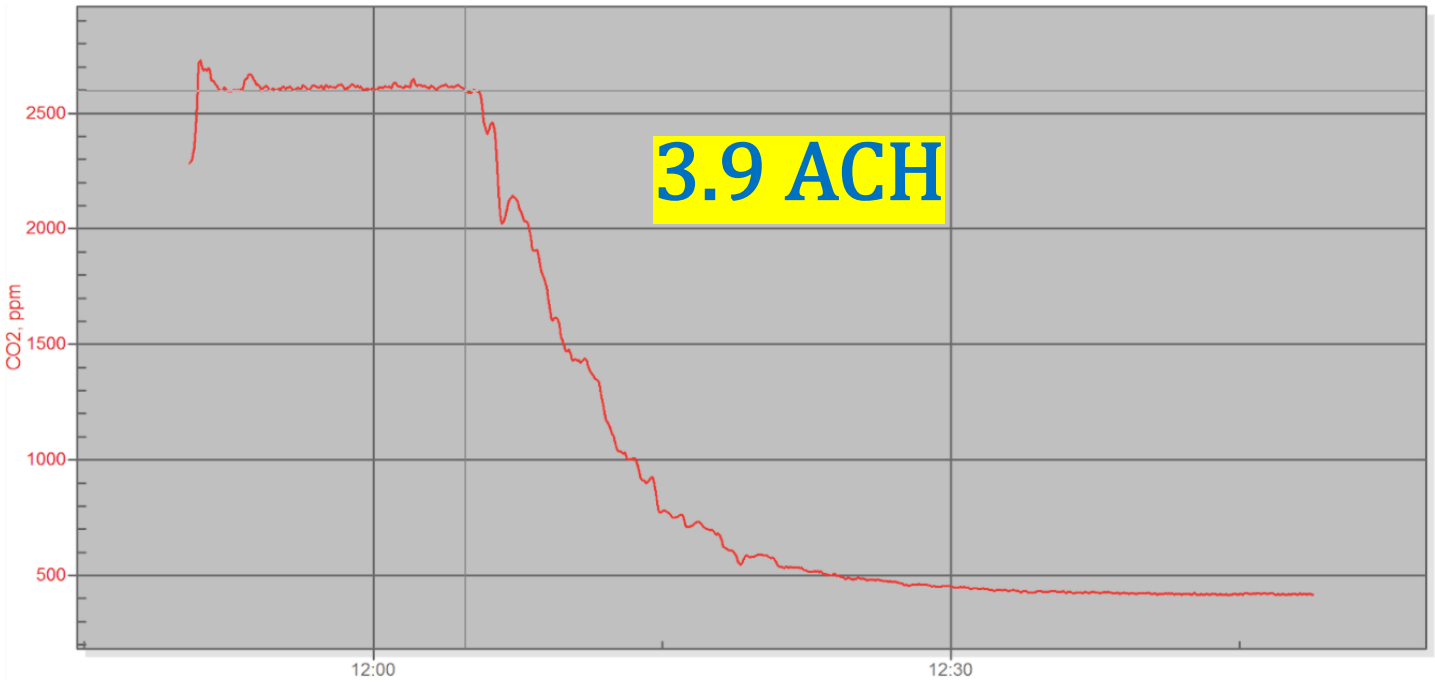

2500
2000
1500
1000
500
CO2, ppm
12:00
12:30

C_1 = 2410 ppm

C_2 = 440 ppm

t = 26 min

ppm = parts per million

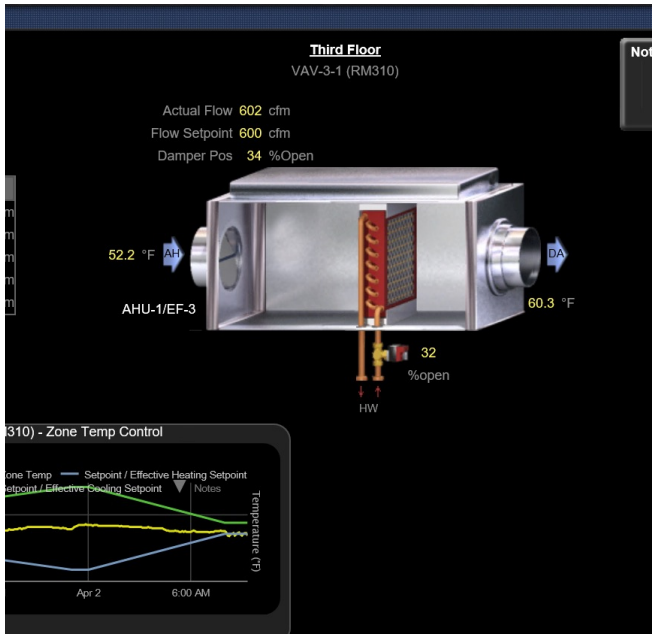


$$ACH = [\ln(C_1/C_2)]*60/t$$

Incorporating Ambient CO_2 May Increase Accuracy for CO_2 ACH calculations

$$ACH = \frac{-1 * ln\left(\frac{C_{end} - C_{ambient}}{C_{start} - C_{ambient}}\right)}{t_{end} - t_{start}}$$

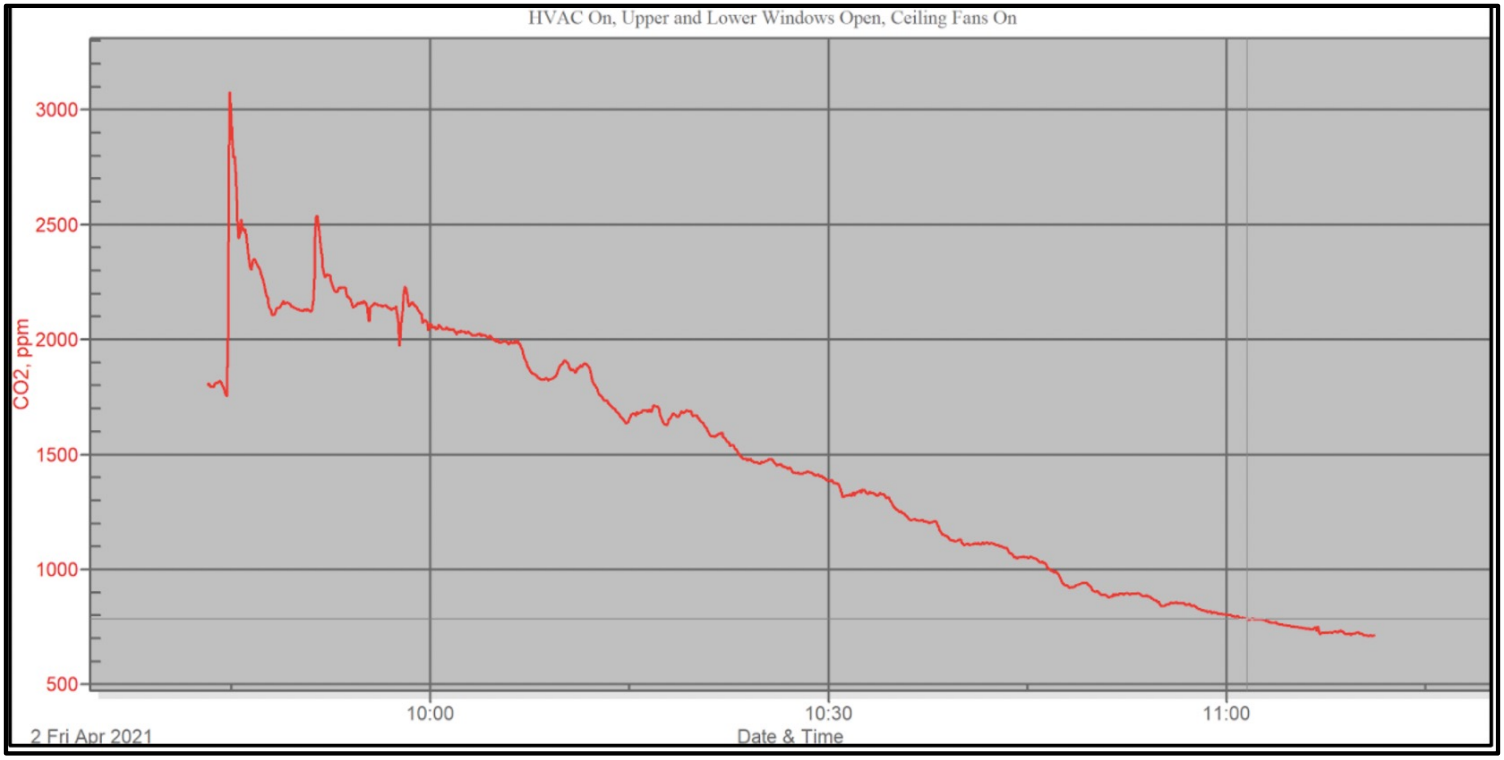
https://schools.forhealth.org/ventilation-guide/



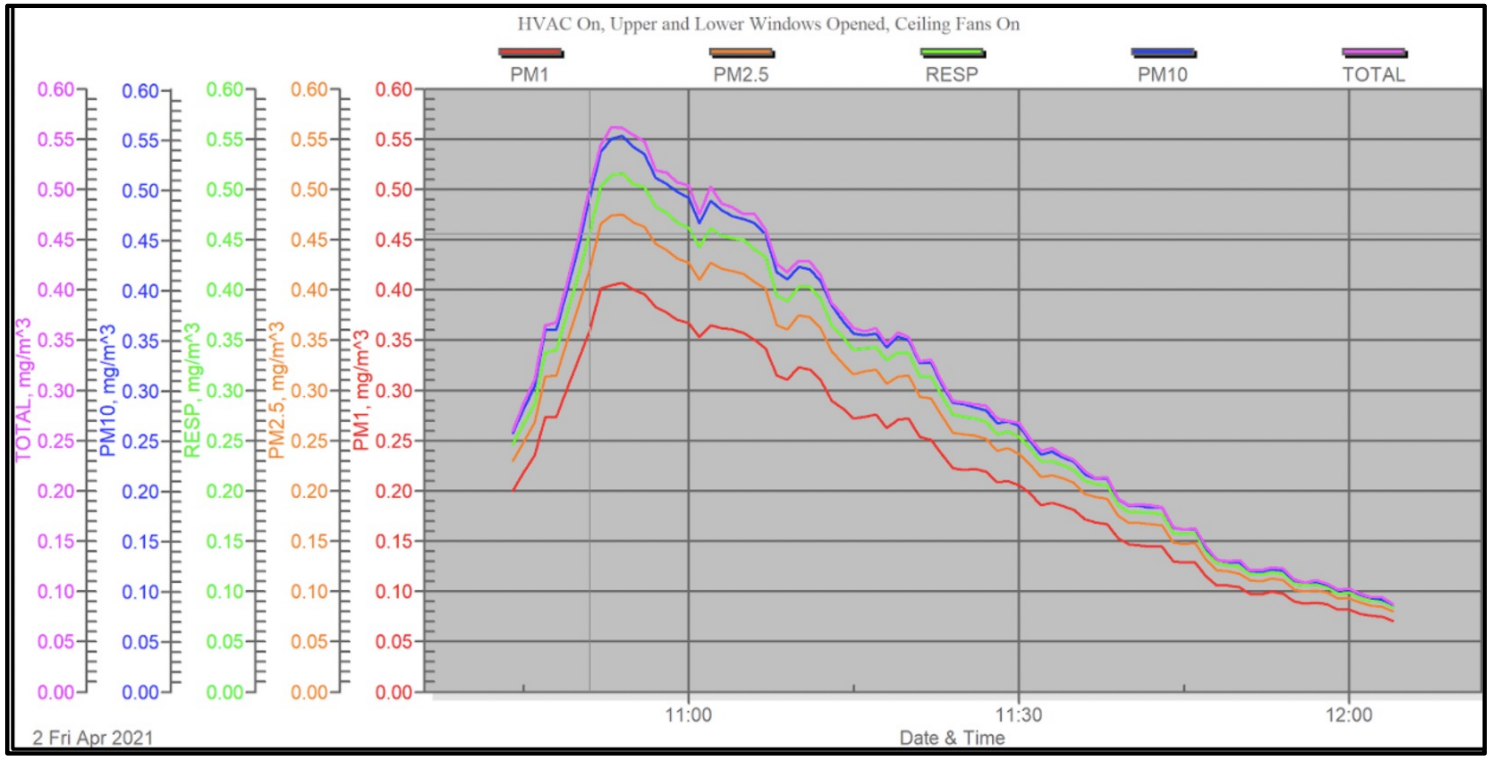
Test 2: HVAC, Windows Open, Ceiling Fans On

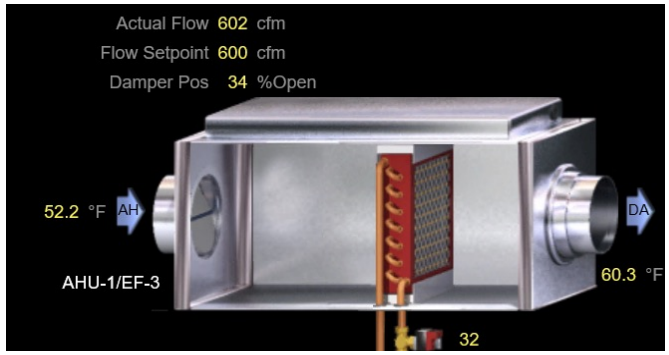
HVAC: Heating, Ventilation, and Air Conditioning

1.1 ACH


HVAC On, Upper and Lower Windows Open, Ceiling Fans On
CO2, ppm
3000
2500
2000
1500
1000
500
10:00
10:30
11:00
2 Fri Apr 2021
Date & Time

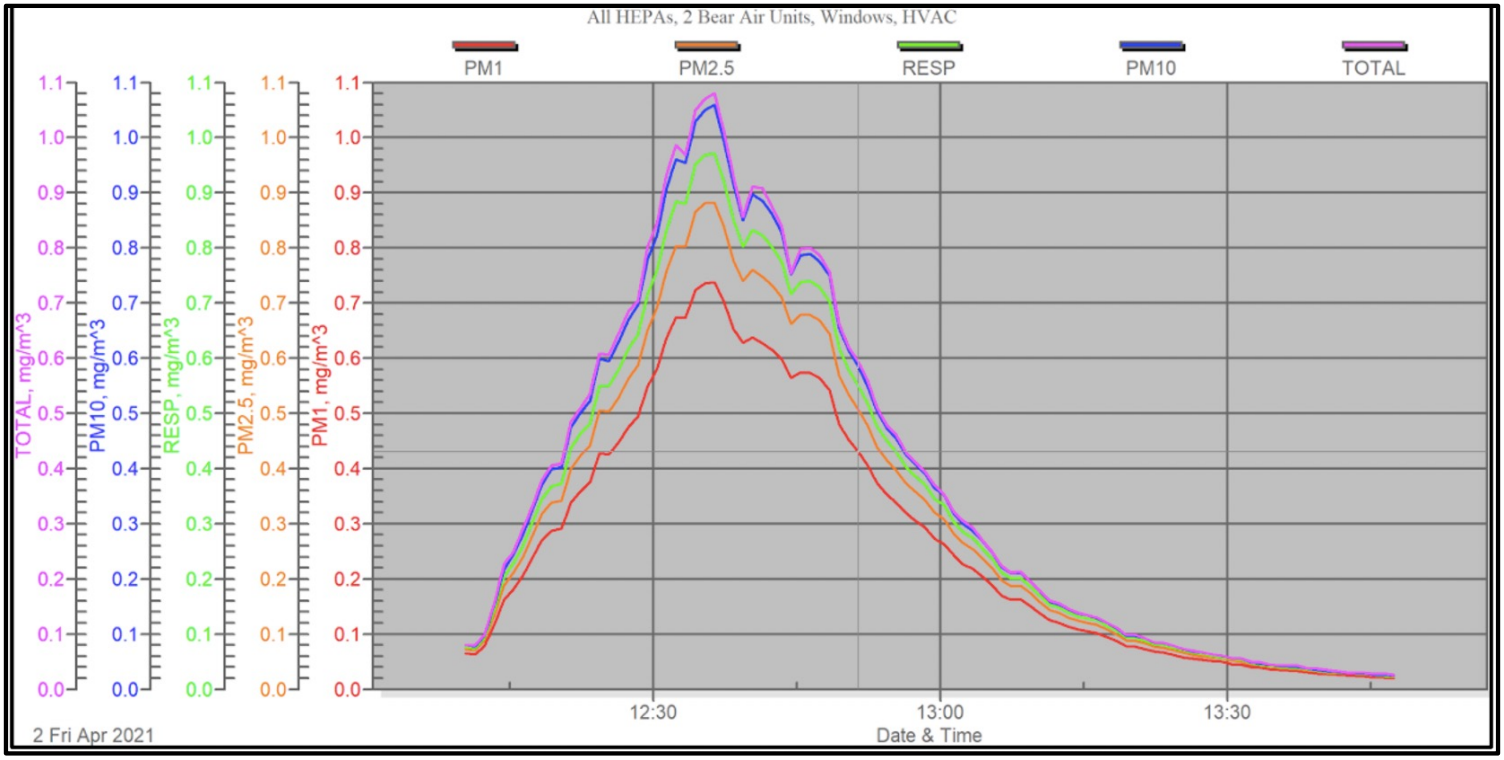
1.4 ACH


HVAC On, Upper and Lower Windows Opened, Ceiling Fans On
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
11:00
11:30
12:00
2 Fri Apr 2021
Date & Time

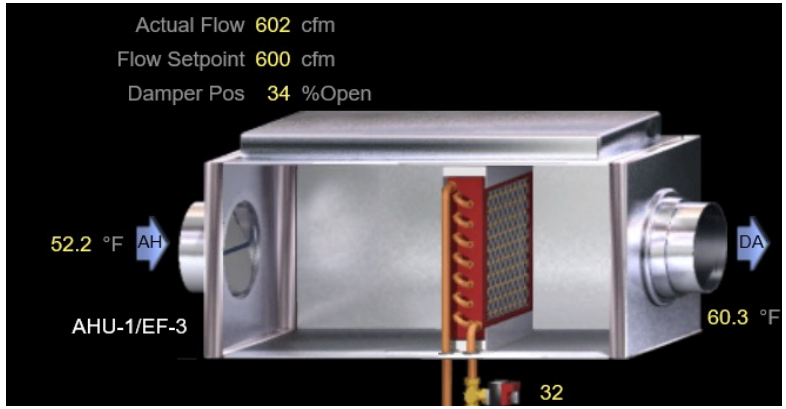


“Kitchen Sink” TEST

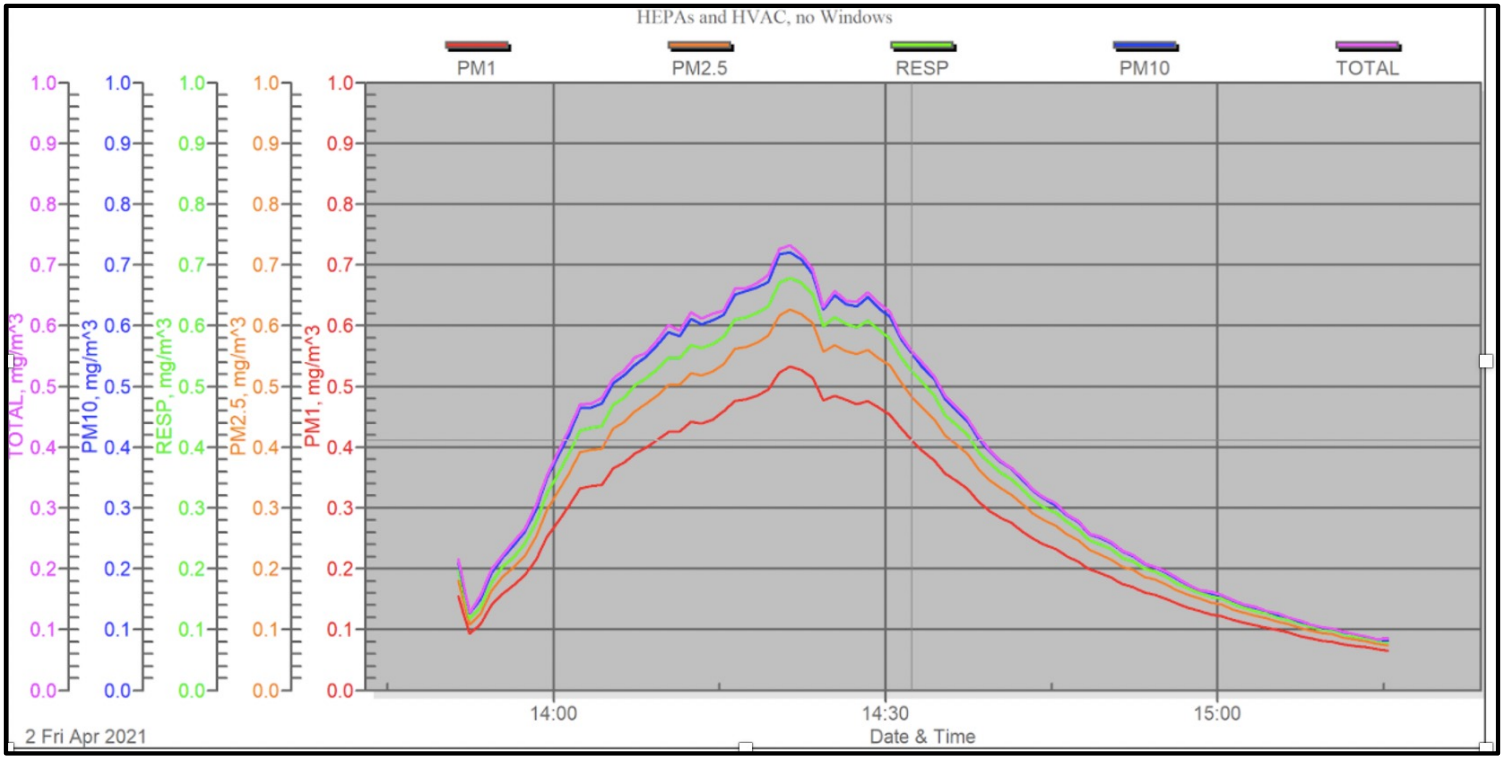
3.0 ACH


All HEPAs, 2 Bear Air Units, Windows, HVAC
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
12:30
13:00
13:30
2 Fri Apr 2021
Date & Time

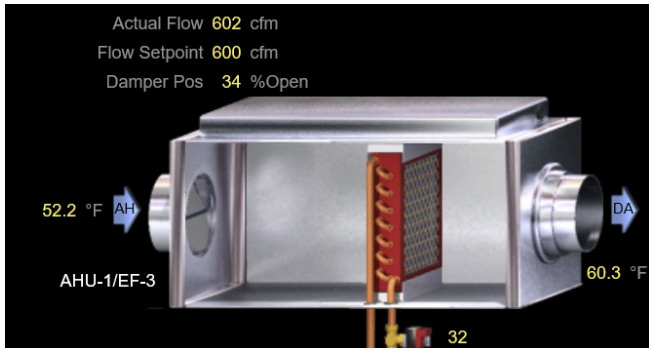
“HVAC/HEPA” TEST



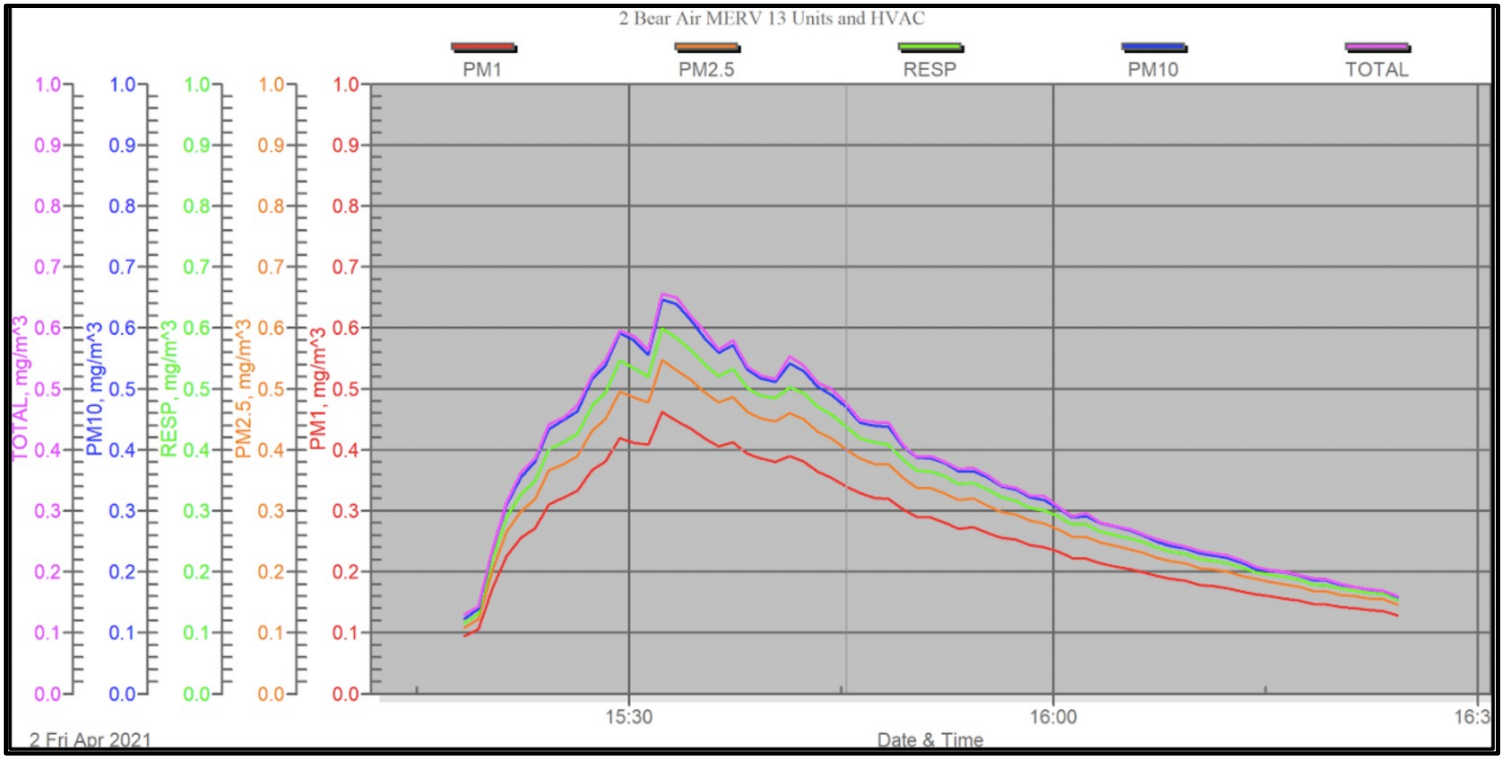
2.6 ACH


HEPAs and HVAC, no Windows
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
14:00
14:30
15:00
2 Fri Apr 2021
Date & Time

“HVAC, Bear Air, and Fans” TEST

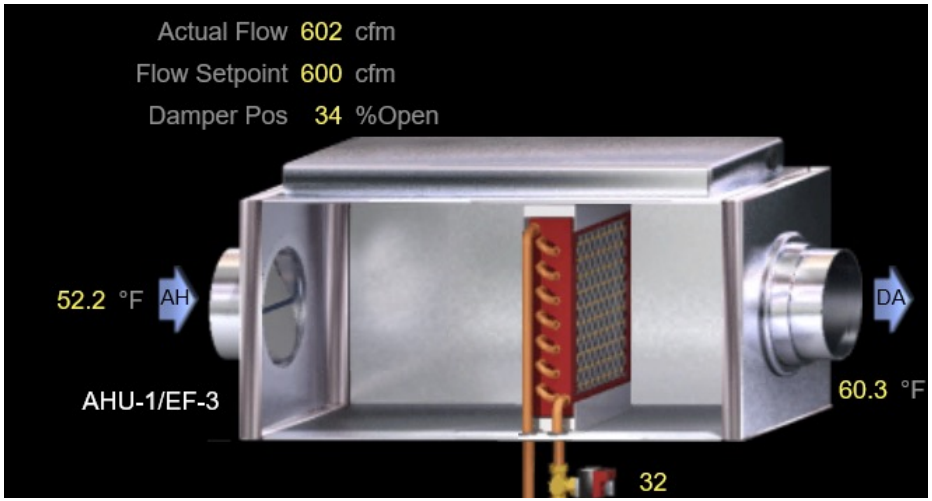


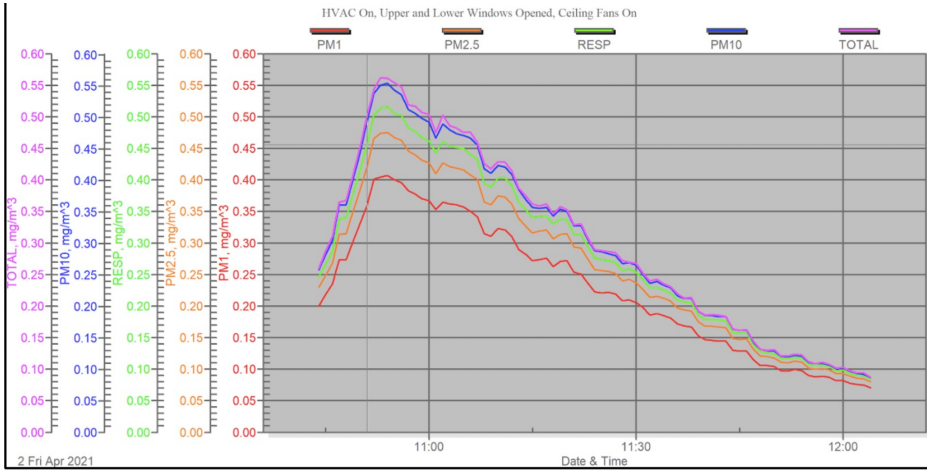
1.8 ACH

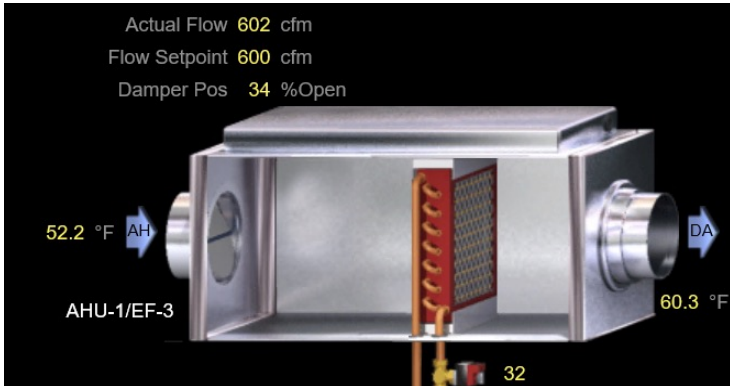

2 Bear Air MERV 13 Units and HVAC
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
15:30
16:00
2 Fri Apr 2021
Date & Time

Well, does ACH add up?

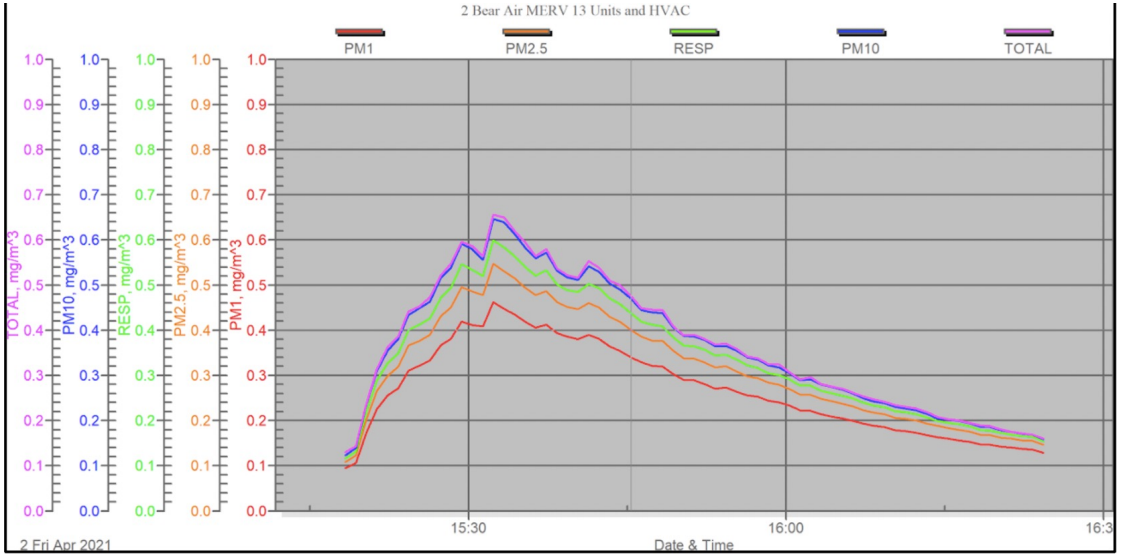
1.4 ACH


Actual Flow 602 cfm
Flow Setpoint 600 cfm
Damper Pos 34 %Open
52.2 °F
AH
DA
60.3 °F
AHU-1/EF-3
32


HVAC On, Upper and Lower Windows Opened, Ceiling Fans On
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
11:00
11:30
12:00
2 Fri Apr 2021
Date & Time

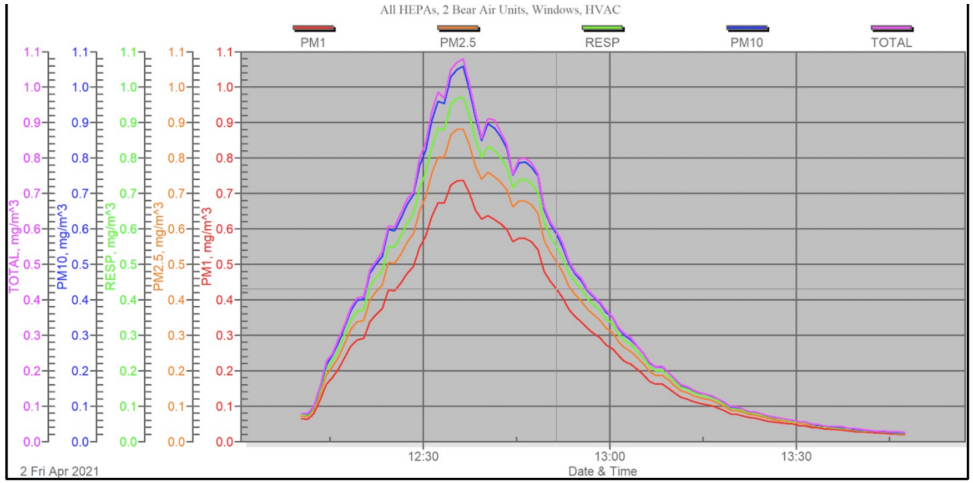

Actual Flow 602 cfm
Flow Setpoint 600 cfm
Damper Pos 34 %Open
52.2 °F
AH
DA
60.3 °F
AHU-1/EF-3
32


20 inches


2 Bear Air MERV 13 Units and HVAC
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
15:30
16:00
2 Fri Apr 2021
Date & Time

1.8 ACH

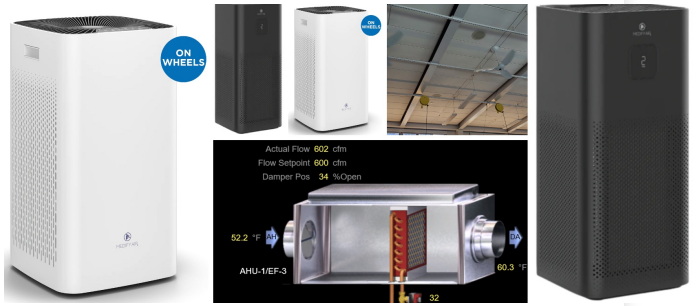
3.0 ACH


All HEPAs, 2 Bear Air Units, Windows, HVAC
PM1
PM2.5
RESP
PM10
TOTAL
TOTAL, mg/m^3
PM10, mg/m^3
RESP, mg/m^3
PM2.5, mg/m^3
PM1, mg/m^3
12:30
13:00
13:30
2 Fri Apr 2021
Date & Time

3.0 ACH

0.4 ACH

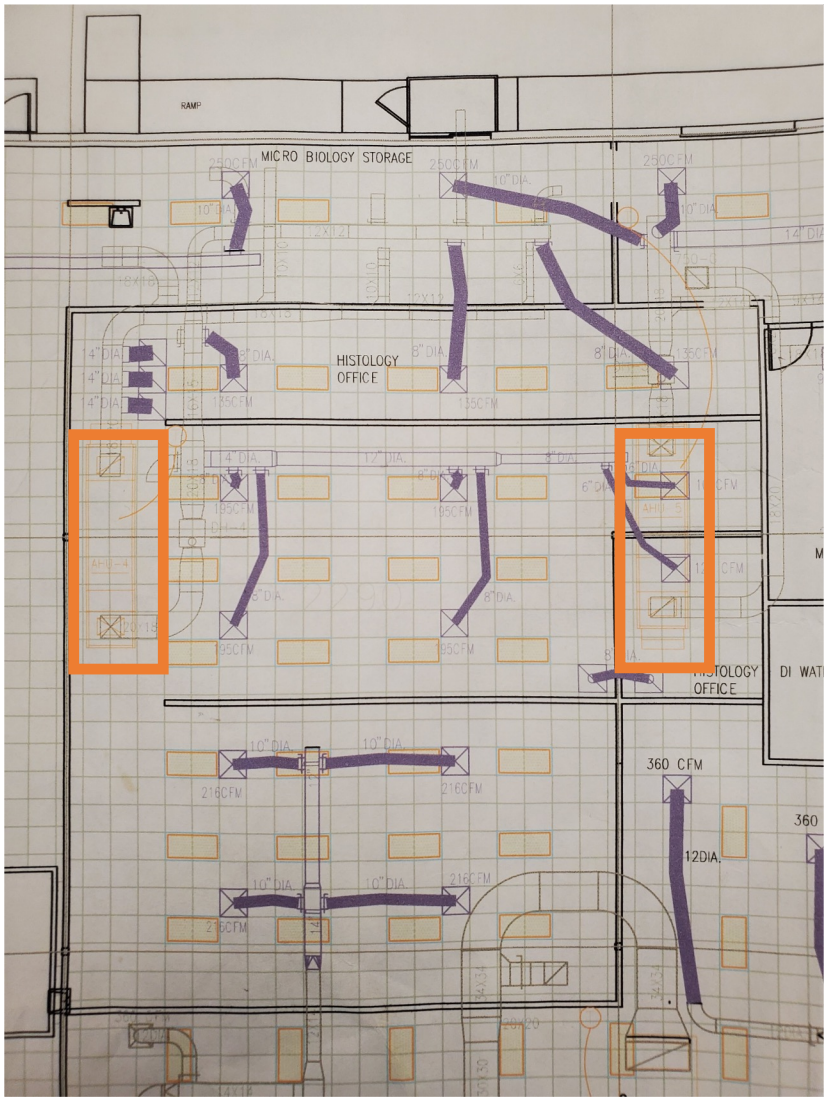
2.6 ACH

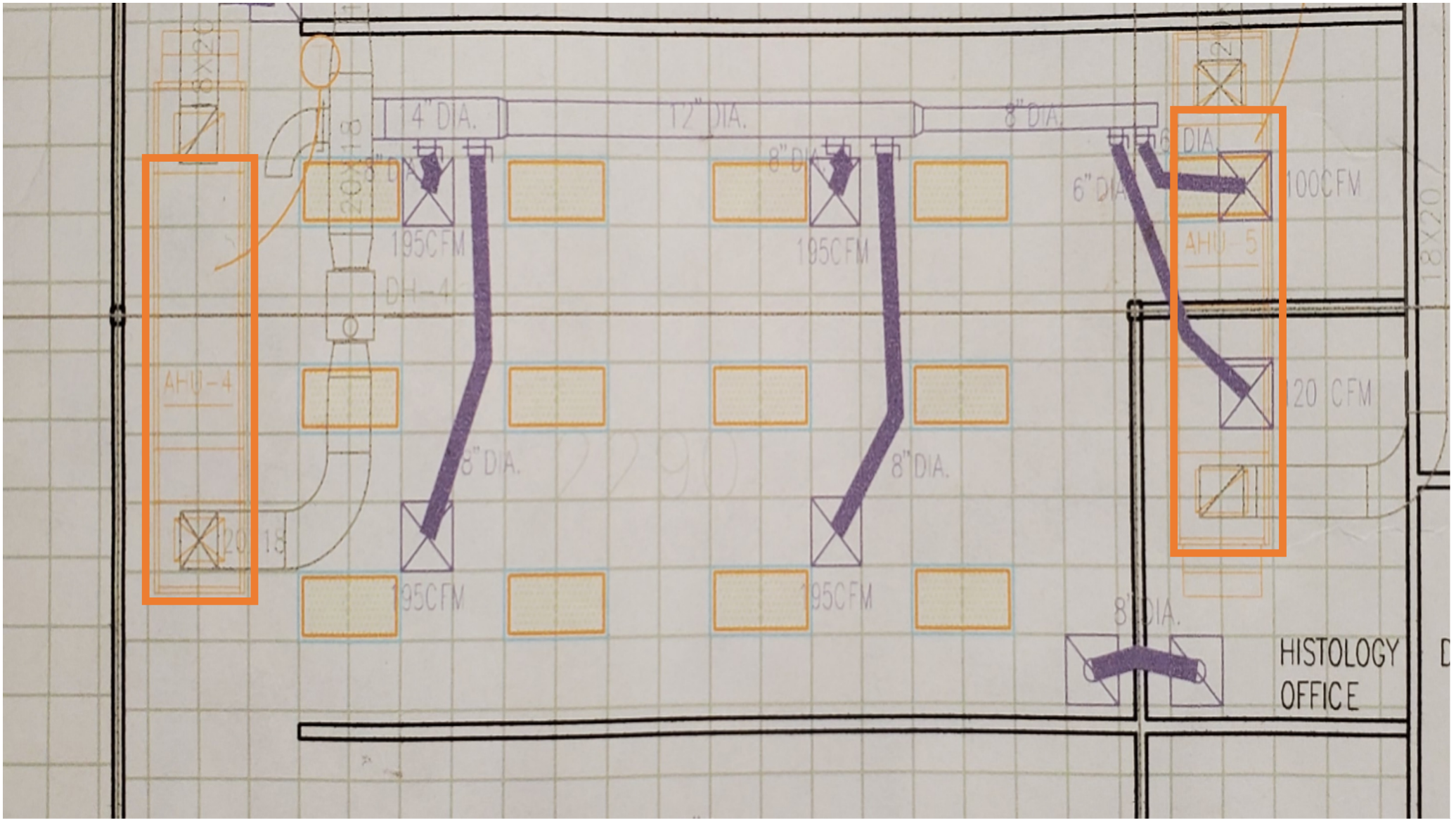


Air Changes Per Hour Calculations

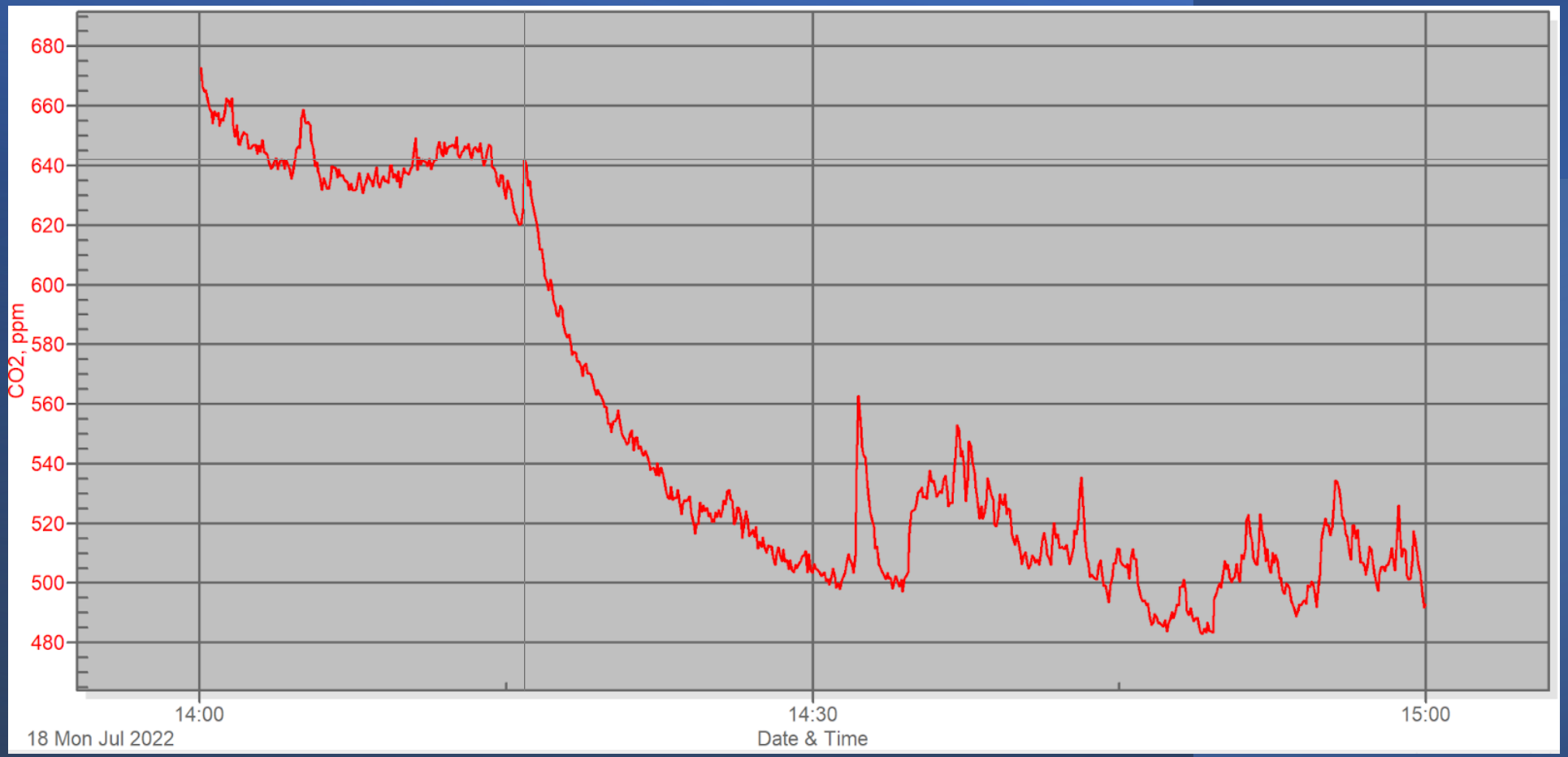
Test	Estimated ACH	CO_2 ACH	PM 1.0µm ACH
1 No HVAC	>1	0.68	0.80
2 HVAC	1.1	1.1	1.4
3 HVAC+HEPA+MERV	4.0	N/A	3.0
4 HVAC+HEPA	3.5	N/A	2.6
5 HVAC+MERV	1.6	N/A	1.8

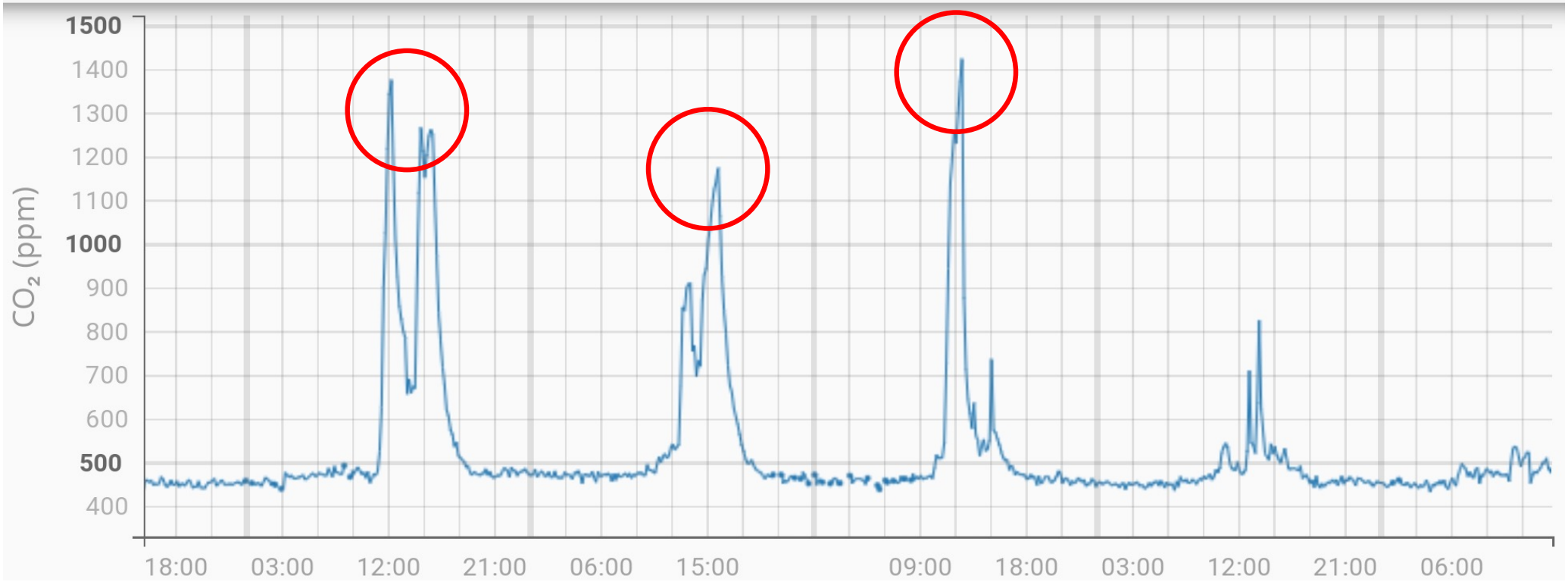

Thermo Shandon
1
GROSSING
#1

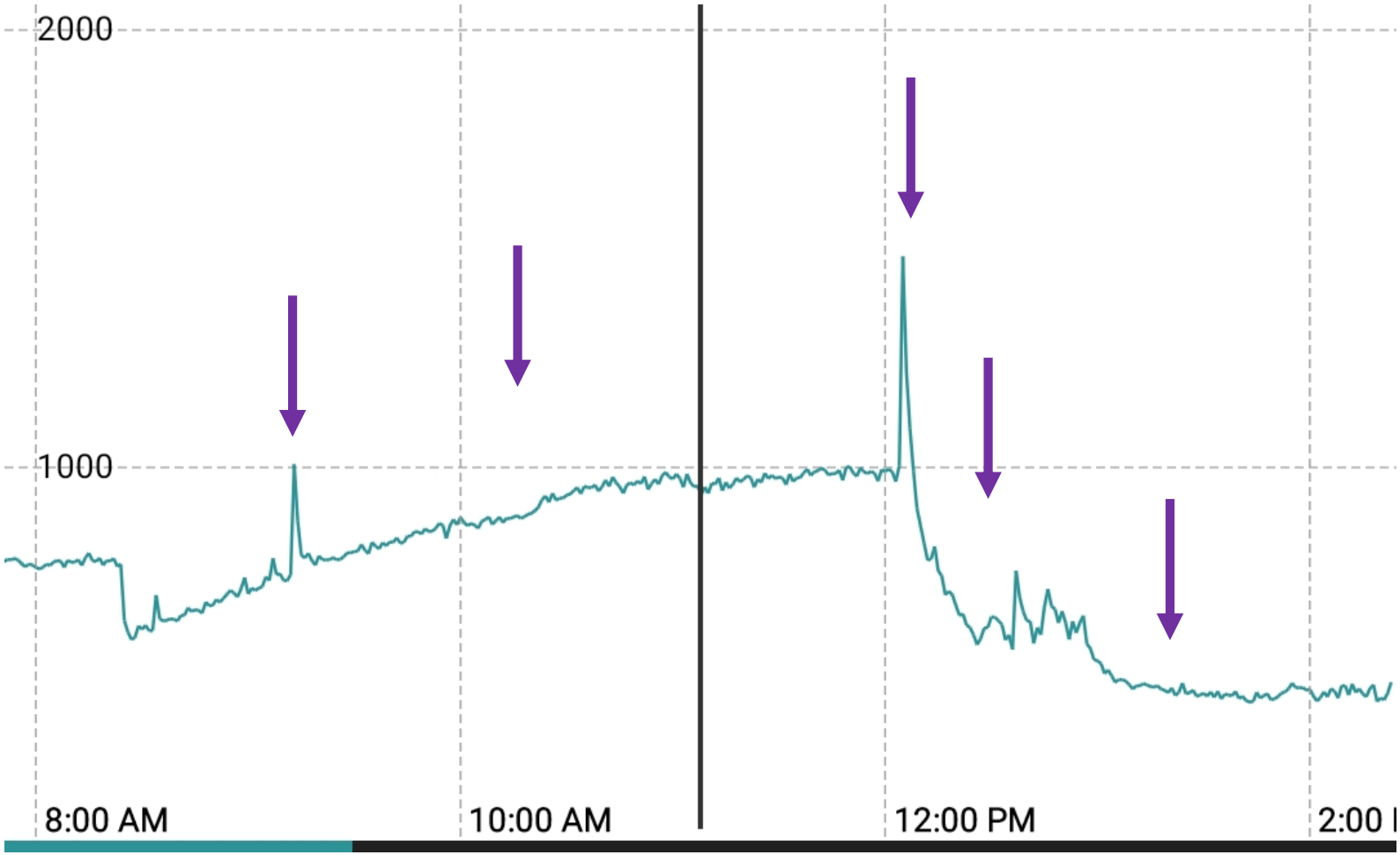

RAMP
MICRO BIOLOGY STORAGE
HISTOLOGY
OFFICE
HISTOLOGY
OFFICE
360 CFM
12DIA.


14" DIA.
12" DIA.
8" DIA.
6" DIA.
195CFM
195CFM
DH-4
AHU-4
AHU-5
100CFM
120 CFM
8" DIA.
8" DIA.
195CFM
195CFM
8" DIA.
HISTOLOGY
OFFICE


3
4
2


680
660
640
620
600
580
560
540
520
500
480
CO2, ppm
14:00
14:30
15:00
18 Mon Jul 2022
Date & Time


1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
CO_2 (ppm)
18:00
03:00
12:00
21:00
06:00
15:00
09:00
18:00
03:00
12:00
21:00
06:00


2000
1000
8:00 AM
10:00 AM
12:00 PM
2:00

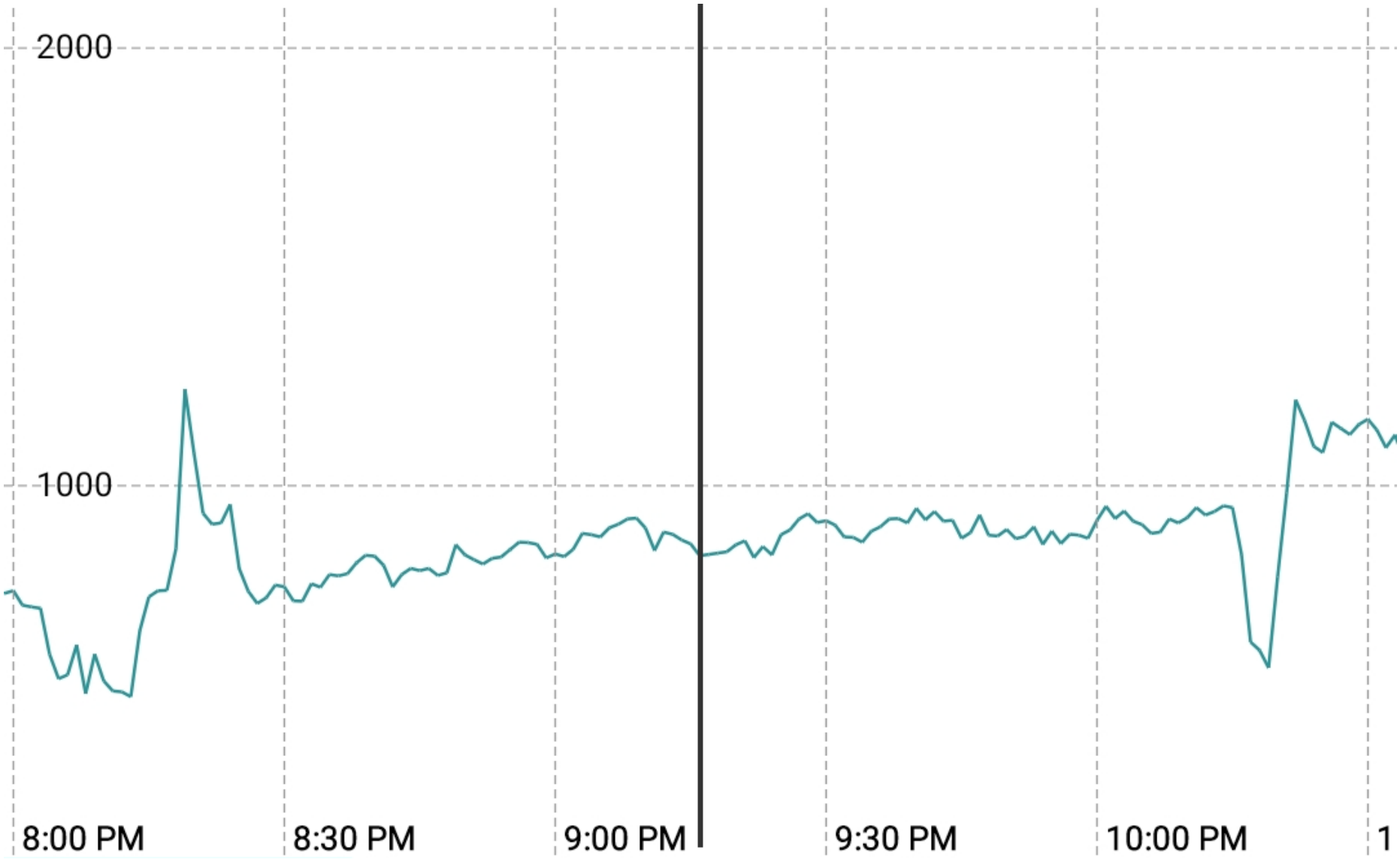
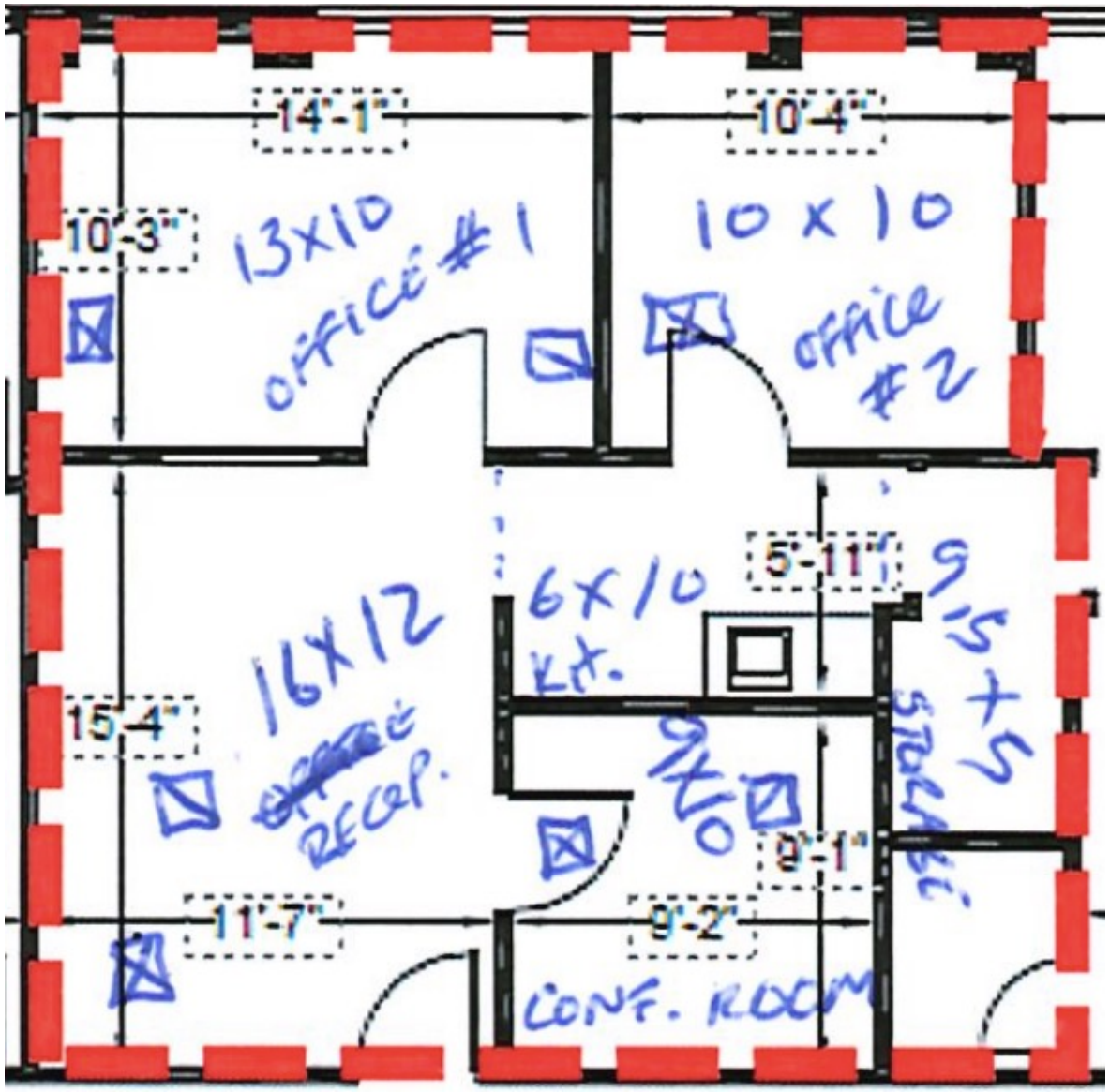

2000
1000
8:00 PM
8:30 PM
9:00 PM
9:30 PM
10:00 PM
1

Table 6-4 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Well-Mixed Air Distribution Systems	
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is less than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is equal to or greater than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	1.0
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply outlet located more than half the length of the space from the exhaust, return, or both	0.8
Makeup supply outlet located less than half the length of the space from the exhaust, return, or both	0.5
Stratified Air Distribution Systems (Section 6.2.1.2.1)	
Floor supply of cool air where the vertical throw is greater than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height less than or equal to 18 ft (5.5 m) above the floor	1.05
Floor supply of cool air where the vertical throw is less than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height less than or equal to 18 ft (5.5 m) above the floor	1.2
Floor supply of cool air where the vertical throw is less than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height greater than 18 ft (5.5 m) above the floor	1.5
Personalized Ventilation Systems (Section 6.2.1.2.2)	
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with ceiling supply of cool air and ceiling return	1.40
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with ceiling supply of warm air and ceiling return	1.40
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with a stratified air distribution system with nonaspirating floor supply devices and ceiling return	1.20
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with a stratified air distribution system with aspirating floor supply devices and ceiling return	1.50

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf


AED
AED
EMERGENCY DEFIBRILLATOR
Warning!
ALARM WILL SOUND WHEN DOOR OPENS
AED
Employees Only
Empleados Solamente
Dispensary
ATTENTION


14'-1"
10'-4"
10'-3"
13X10
OFFICE #1
10 x 10
OFFICE #2
5'-11"
9'5"x5'
STORAGE
16X12
RECEP.
6X10
KIT.
9X10
15'-4"
9'-1"
11'-7"
9'-2"
CONF. ROOM

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COVID-19 Information — CPE Summer Class Update

Construction Blueprint and Plan Reading

https://cpe.ucdavis.edu/course/construction-blueprint-and-plan-reading

Thank you!

David Michael Moore, MPH, CIH

Principal Consultant, CEO

Intrinsic EH&S

info@intrinsic-ehs.com