California Industrial Hygiene Council

30th CIHC Professional Development Seminar

December 6-8, 2021 | Long Beach, CA

Assessing Ventilation to Mitigate COVID Risk in Occupied Buildings

RHP RISK MANAGEMENT
Consulting Health Scientists

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Unprecedented.

As the pandemic unfolded, guidance emerged from authoritative sources. The guidance evolved as our understanding of risk factors, modes of transmission, and effective mitigation measures came into focus.

Photo by Getty Images: https://www.yalemedicine.org/news/covid-19-infodemic

Obsessively cleaning surfaces for COVID-19 unnecessary and may do more harm than good, CDC says

https://www.mlive.com/public-interest/2021/04/obsessively-cleaning-surfaces-for-covid-19-unnecessary-and-may-do-more-harm-than-good-cdc-says.html

CORONAVIRUS CRISIS

A new study says coronavirus can survive on surfaces for up to 28 days. Should you be worried?

Although the study's findings are scientifically significant, their relevance to the everyday transmission of the virus remains uncertain.

https://scroll.in/article/975805/a-new-study-says-coronavirus-can-survive-on-surfaces-for-up-to-28-days-should-you-be-worried

News

Do Public Toilets Pose a Risk of COVID-19 Transmission?

Study explores flushing power to test risk of COVID-19 transmission

https://www.labmanager.com/news/do-public-toilets-pose-a-risk-of-covid-19-transmission-25723

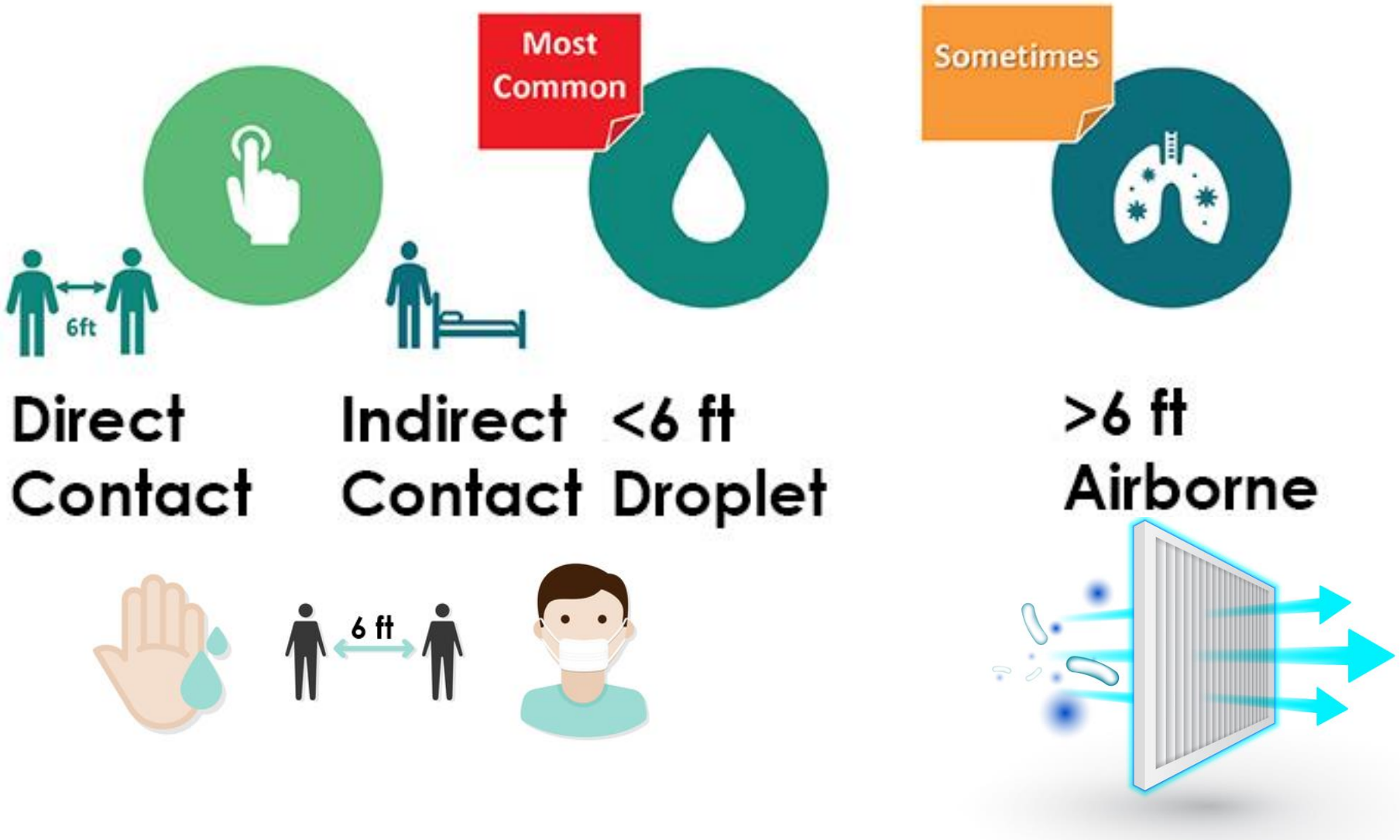
[WEBMD NEWS BRIEF]

Study: Poor Ventilation Could Spread COVID Indoors

By Carolyn Crist

https://www.webmd.com/lung/news/20210406/study-poor-ventilation-could-spread-covid-indoors

Exposure Routes & Control Measures



Authoritative Guidance to Reduce Risk

Guidance documents from international, national, state, and local agencies; County/city health departments; industry organizations.

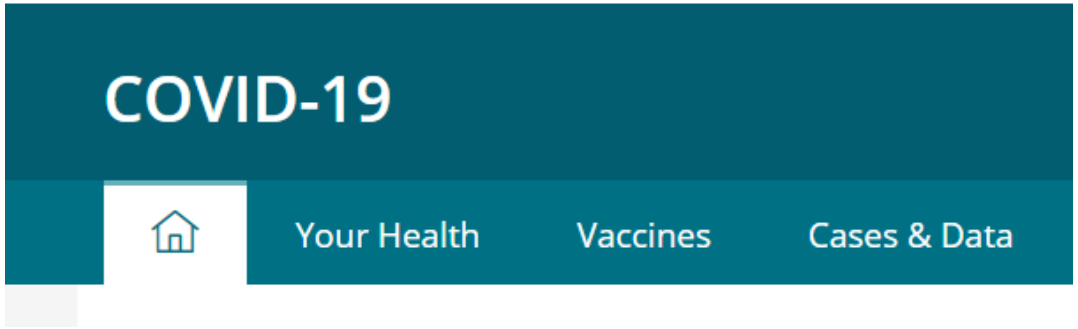
ASHRAE®

AIHA®
HEALTHIER WORKPLACES | A HEALTHIER WORLD

World Health Organization

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION™

CDC Guidance



- Cleaning and Disinfecting [1]
  - "When no people with confirmed or suspected COVID-19 are known to have been in a space, cleaning once a day is usually enough"
  - "If there has been a sick person or someone who tested positive for COVID-19 in your facility within the last 24 hours, you should clean AND disinfect the space."
- Ventilation in Buildings [2]
  - "Increase the introduction of outdoor air"
  - "Use fans to increase the effectiveness of open windows"
  - "Run the HVAC system at maximum outside airflow for 2 hours before and after the building is occupied."

[1] https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html
[2] https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html

CDC on Modes of Transmission

- Respiratory viruses, such as COVID-19, are principally transmitted by either **droplet, airborne, or contact transmission**. (Source-Pathway-Receptor model)
- SARS-CoV-2 (COVID-19) is spread:
  - **principal mode** from infected people through exposure to respiratory droplets carrying infectious virus.
  - increasing ventilation can reduce airborne transmission.
  - **possibly** through contact with contaminated surfaces, but low risk. (i.e., fomite transmission)

https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/scientific-brief-sars-cov-2.html

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
- Pre- or Post-Occupancy Flushing Strategy
- 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
- Shutdown a Building Temporarily-FAQ
- System Manual
- Reopening During Epidemic Conditions in Place

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/about/news/2021/ashrae-epidemic-task-force-releases-updated-building-readiness-guide

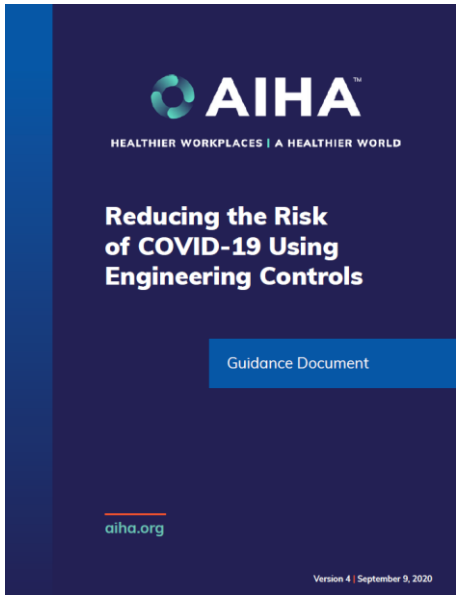
More outside air is better

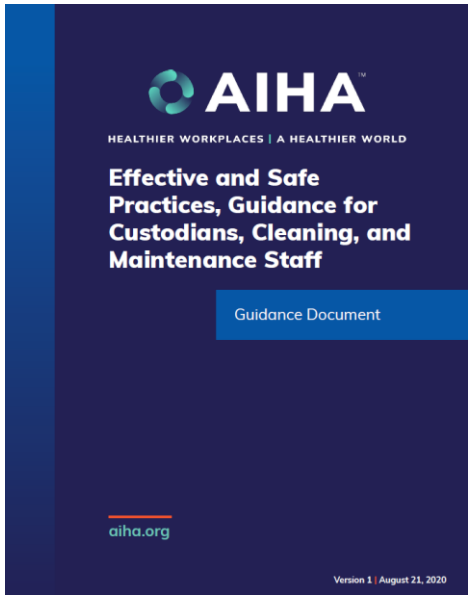
… so long as the system can maintain temperature and control humidity within the space

Cliffs Notes®

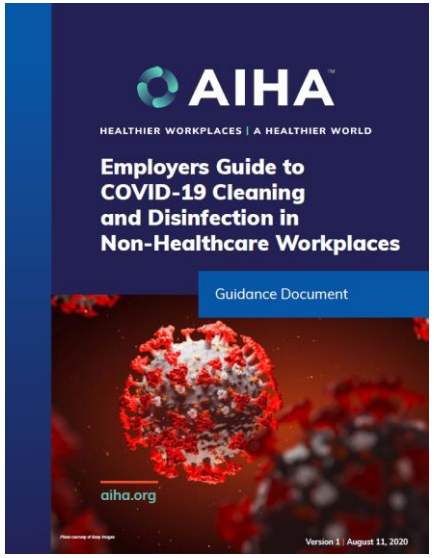
AIHA Guidance Documents

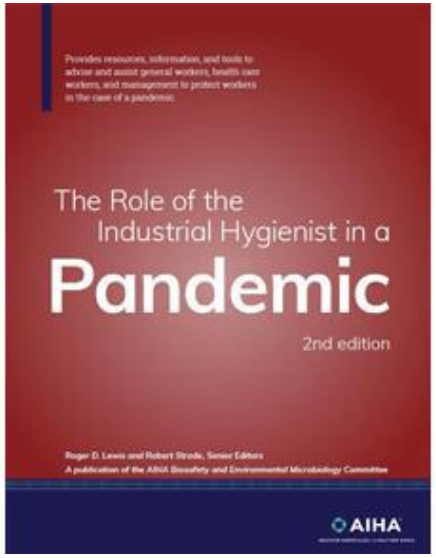
- 27 industry-specific guidance documents.
- General guidance on cleaning and disinfecting protocols and building ventilation / engineering controls.





https://www.aiha.org/public-resources/consumer-resources/coronavirus_outbreak_resources





https://www.backtoworksafely.org/

Improved Ventilation Reduces Risk

GUIDANCE DOCUMENT

Reducing the Risk of COVID-19 Using Engineering Controls

Engineering controls that can keep infectious aerosols at shallow levels indoors offer the greatest promise to protect non-healthcare workers and other vulnerable populations as we reopen our businesses and workplaces. Engineering controls have historically proven to be more reliable because they are less prone to human error.

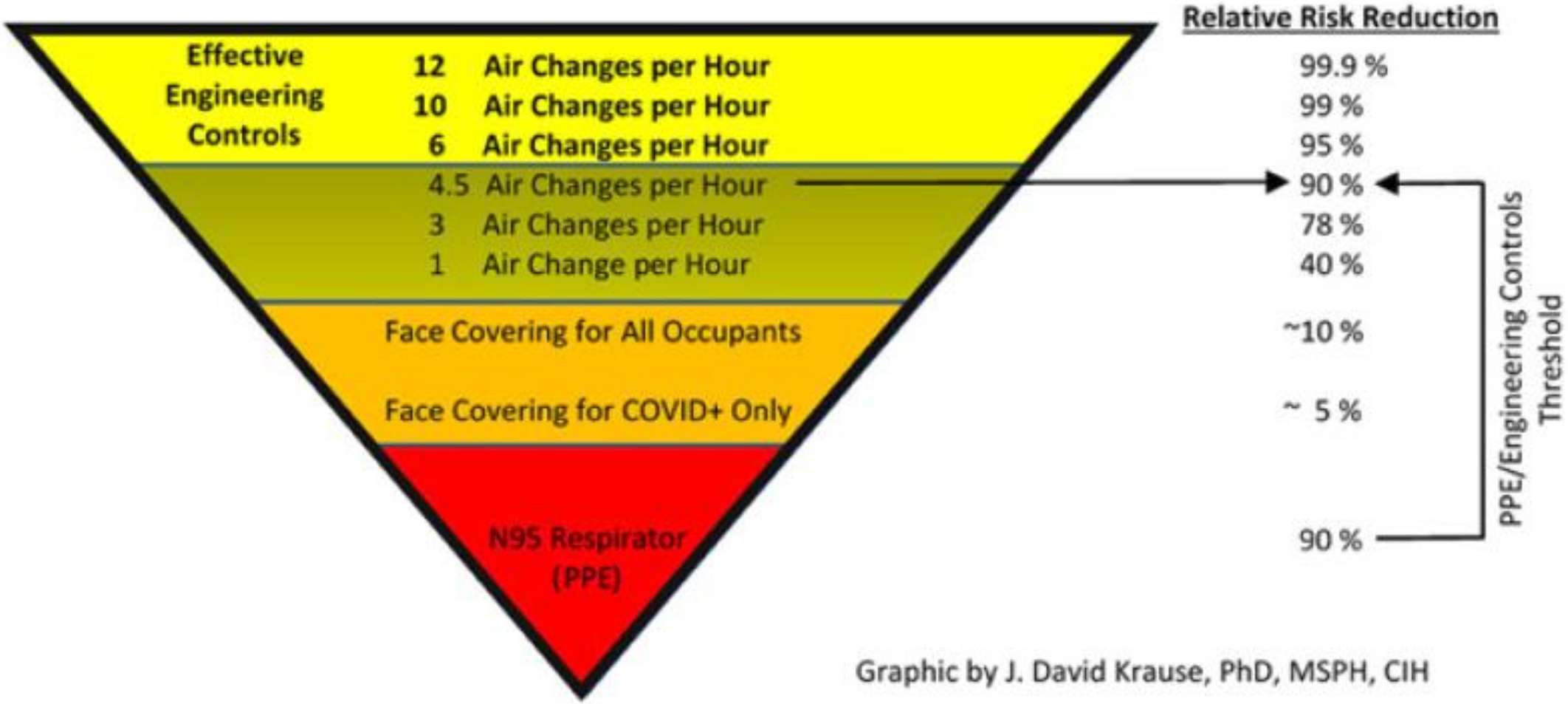
Download document | Versión en español

Back to Work Safely™

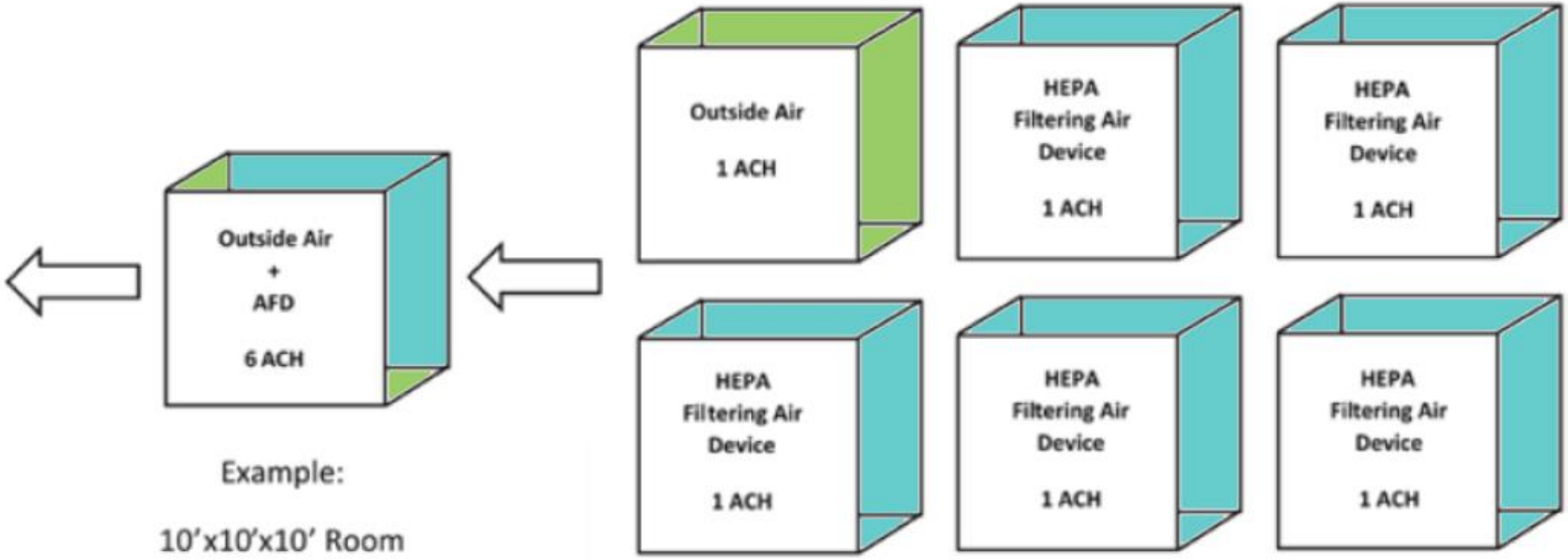
Cliffs Notes®

- More “clean air”
  - Outside air
  - Filtered recirculated air

Equating “Clean Air Delivery Rate” to Risk Reduction



Sources of “Clean Air” to Achieve Target Risk Reduction Levels



Example:

10’x10’x10’ Room

1,000 ft^3/hr = 1 Air Change per Hour

6,000 ft^3/hr = 100 ft^3/min = 6 ACH

Six (6) times the volume of the room in “clean” air each hour

Applying the Guidance in Practice

- How to determine rate of outside air replacement in a building?
  1. **Calculate** from design specifications.
  2. **Measure**
     1. Volumetric airflow delivery rates; assumptions on air-mixing
     2. Tracer-gas decay
     3. Other approaches

Calculation Approach

- Design schedules
- ASHRAE 62.1
  - People-rate
  - Area-rate
- BMS Logs

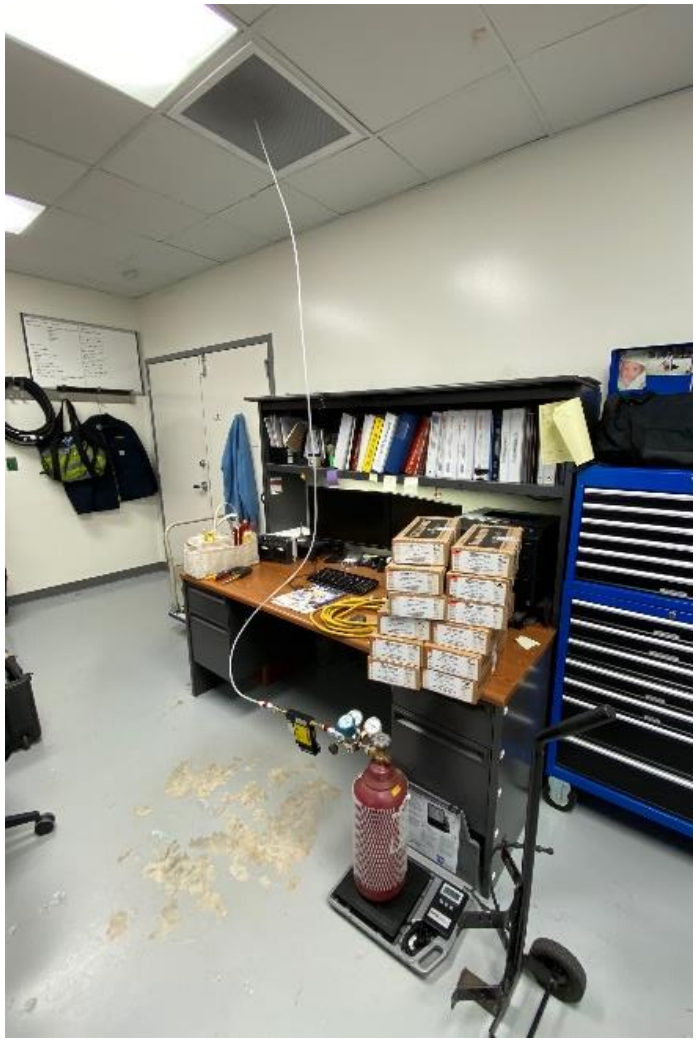
MECHANICAL VENTILATION AND REHEAT

PROJECT NAME:

MECHANICAL VENTILATION (§121(b)2)								
	AREA BASIS			OCCUPANCY BASIS				
A	B	C	D	E	F	G	H	I
Zone/ System	Condition Area (ft^2)	CFM/ per ft^2	Min CFM by Area B x C	Num of People	CFM per Person	Min CFM by Occupant E x F	REQD V.A. Max of D or G	Design Ventilation Air CFM
VAV-3.14	304	0.15	46	3	15	45	46	46
VAV-3.15	1,758	0.15	264	18	15	263	264	264
VAV-3.16	518	0.15	78	5	15	77	78	78
VAV-3.17	168	0.15	25	2	15	24	25	25
VAV-3.18	741	0.15	111	7	15	111	111	111
VAV-3.19	168	0.15	25	2	15	24	25	25
VAV-3.20	525	0.15	79	5	15	78	79	79
VAV-3.21	541	0.15	81	5	15	81	81	81
VAV-3.22	205	0.15	31	2	15	30	31	31
VAV-3.23	1,148	0.15	172	11	15	171	172	172
VAV-3.24	240	0.15	36	2	15	36	36	36
VAV-3.25	499	0.15	75	5	15	74	75	75
			Totals	68			1,022	1,022

Measurement Approach: Tracer Gas

ASTM E741-11(2017)
Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution



Other Approaches

- Understanding **Outside Air** replacement rates only provides *part* of the information needed to understand risk reduction from building ventilation.

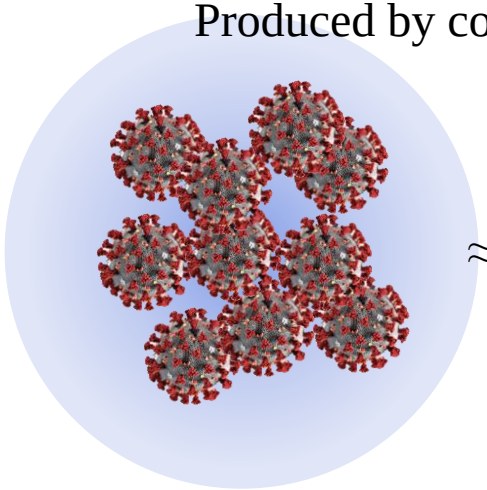
- 100% OA not feasible in many climates. High energy penalty.
- “Building Readiness Guide” developed by ASHRAE’s Epidemic Task Force
  - Maximize OA delivery, within system capabilities to maintain occupant comfort parameters and appropriately regulate relative humidity within the building.
- Need to consider filtration effects as well

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

Filter Efficiency = Risk Reduction Potential

"free" virion  ≈0.1 µm

Droplet nuclei
Produced by coughing



≈ 1 µm

MERV Rating - Actual Particle Size Removed and Efficiency in Percentage

MERV Rating	0.3 – 1.0 Microns*	1.0 – 3.0 Microns	3.0 – 10.0 Microns
1	-	-	< 20%
2	-	-	< 20%
3	-	-	< 20%
4	-	-	< 20%
5	-	-	≥ 20%
6	-	-	≥ 35%
7	-	-	≥ 50%
8	-	≥ 20%	≥ 70%
9	-	≥ 35%	≥ 75%
10	-	≥ 50%	≥ 80%
11	≥ 20%	≥ 65%	≥ 85%
12	≥ 35%	≥ 80%	≥ 90%
13	≥ 50%	≥ 85%	≥ 90%
14	≥ 75%	≥ 90%	≥ 95%
15	≥ 85%	≥ 90%	≥ 95%
16	≥ 95%	≥ 95%	≥ 95%

Bar-On et al. (2020). *SARS-CoV-2 (COVID-19) by the numbers.* https://dx.doi.org/10.7554%2FeLife.57309
Liu et al. (2020). *Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals* https://www.nature.com/articles/s41586-020-2271-3.pdf

Measuring Filtration Contribution to Risk Reduction

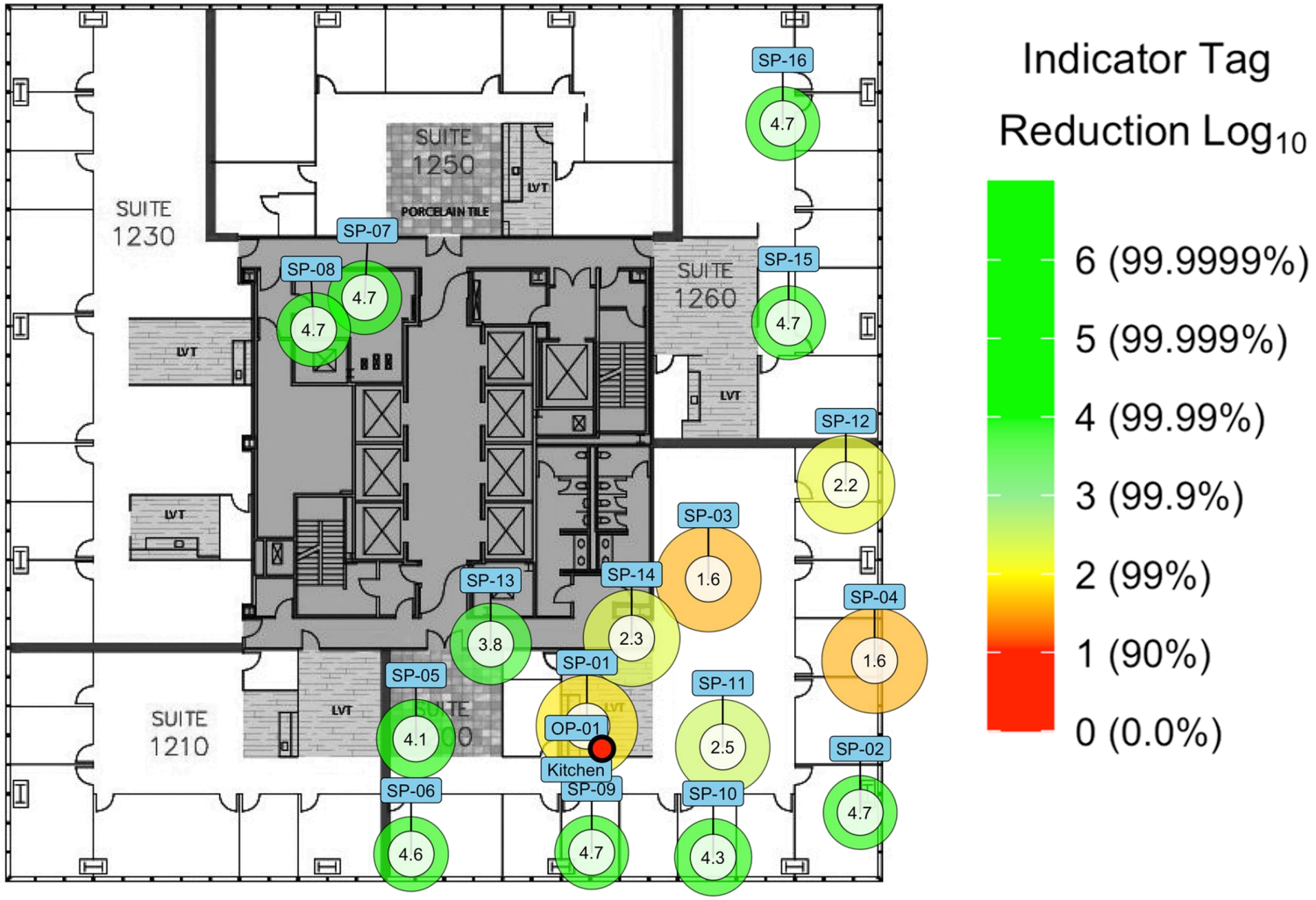
- Gaseous Challenge Agents
- Particulate Challenge Agents
- Infectious Aerosol Surrogates

TRANSCOM/AMC Commercial Aircraft Cabin Aerosol Dispersion Tests
https://www.ustranscom.mil/cmd/docs/TRANSCOM%20Report%20Final.pdf

DNA-tagged Aerosol Challenge Agent

Data Visualization

- Sample points measure Log_{10} reduction of DNA signal from origin point
- Log_{10} units tracked to relative exposure risk scale informed by science
- Visualizations clearly communicate results and inform decisions



Case Study: Salient Findings

- Data-informed Return to Work Strategy:
  - Occupant density / seating arrangements
  - Validation of efficacy for HVAC settings during active pandemic conditions
- Identified Areas of Previously Unknown Concern
  - Isolated VAV programming errors
    - “needle in a haystack” with just a few issues amongst many hundred VAV zones.
- Provided employee confidence in a safe return to work.
- Tracer gas and veriDART™ were used complementary, but how do they compare to each other?

RHP Exposure Sciences Laboratory

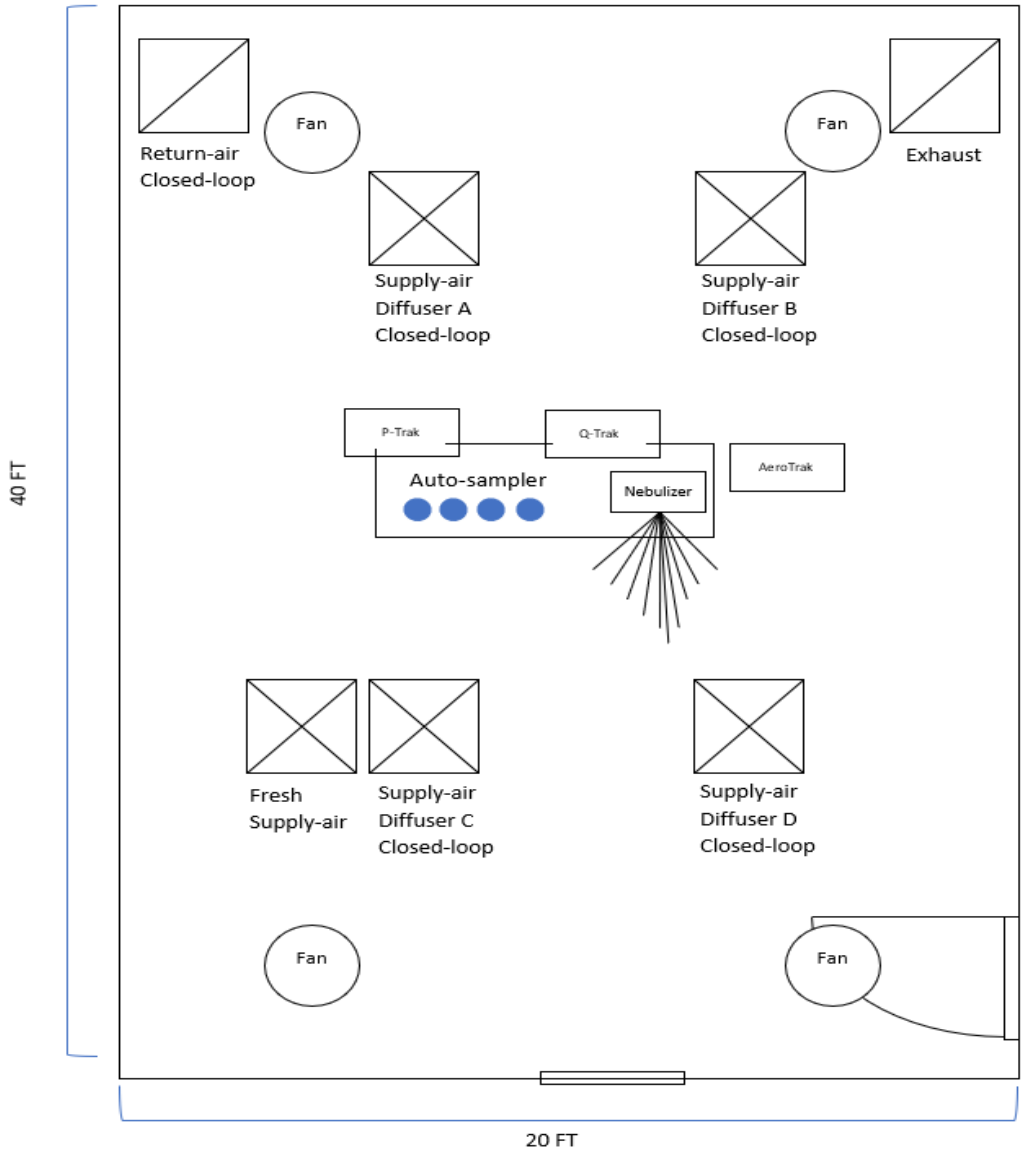
Classroom Replica
20 ft x 40 ft

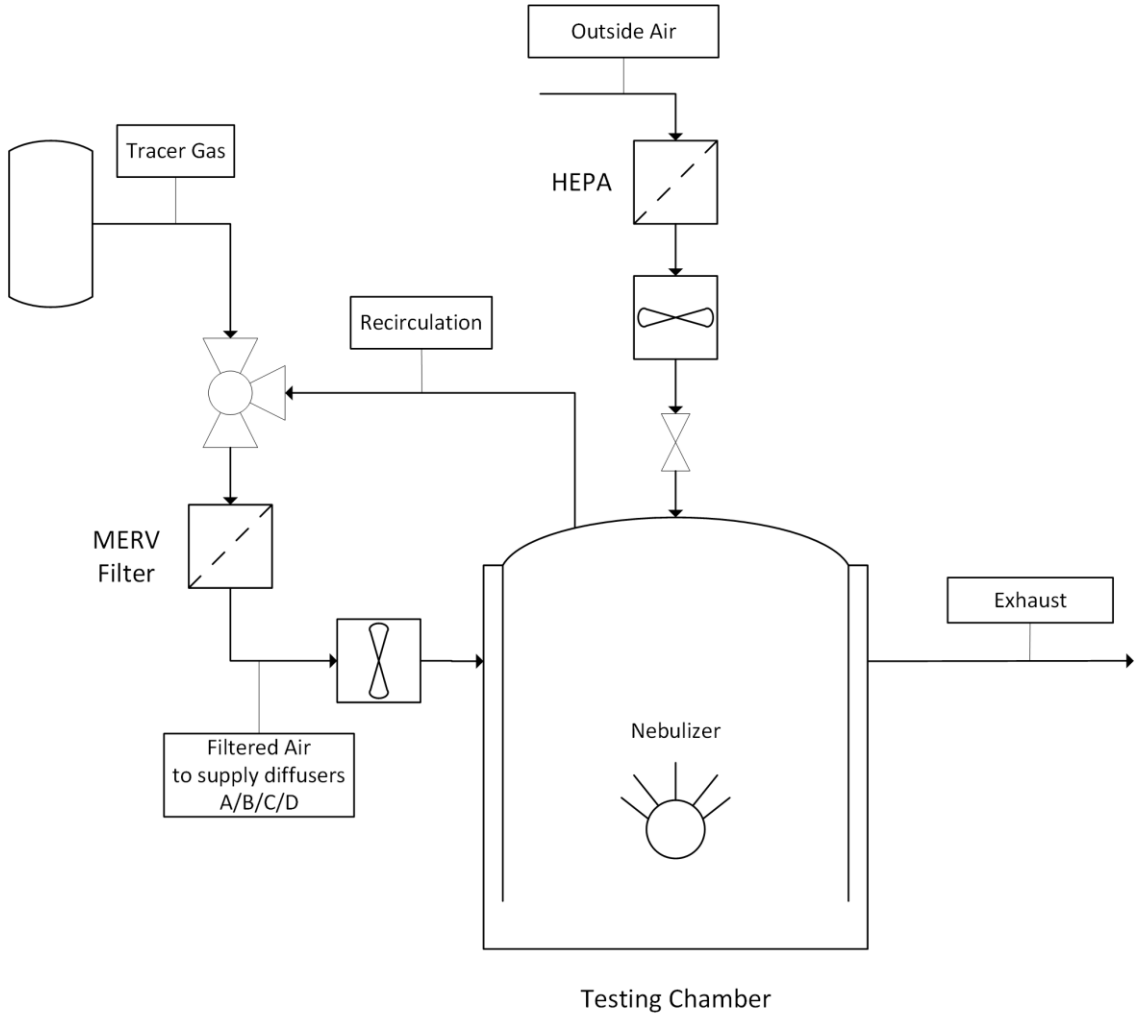
Variable ventilation
0.3 to 8 ACH

Variable filtration
MERV 0,8,13,HEPA

3 Methods
- Tracer gas
- Particle counter
- DNA by qPCR

Study Design: Testing Chamber Layout





Materials and Methods

Condition	Calculated Outside Air Change Rate (ACH)	Outside Air Flow Rate (CFM)	Calculated Recirculated Air Change Rate (ACH)	Recirculated Air Flow Rate (CFM)	Filter Type
Zero ACH	None	0	None	0	None
Low ACH – MERV8	1.3	156	1.3	155	MERV8
Low ACH – MERV13	1.3	157	1.3	157	MERV13
Medium ACH – MERV8	2.5	298	2.6	308	MERV8
Medium ACH – MERV13	2.5	298	2.6	310	MERV13
High ACH – No Filter	4.1	489	4.1	491	None
High ACH – MERV8	4.4	526	4.5	535	MERV8
High ACH – MERV13	4.2	500	4.2	508	MERV13

$\underline{CO_2}$

Q-Trak

Model 7575

$\underline{SF_6}$

Innova 1314

Multigas Monitor

Ultrafine Particles

P-Track 8525

TSI, Inc.

Particle counter

AeroTrak 9306

TSI, Inc.

Air Sampler

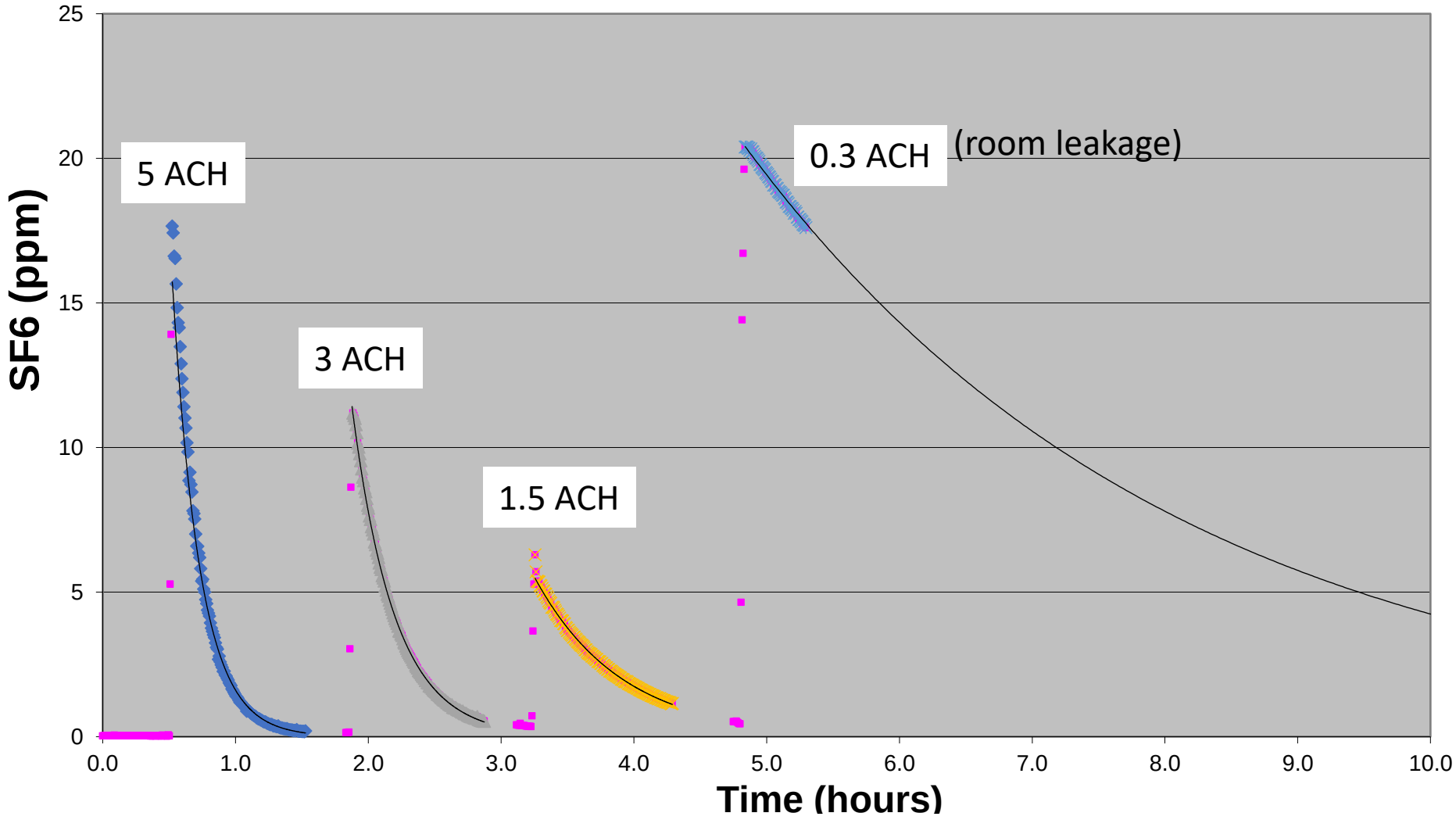
4-Way Auto Sampler

SafeTraces, Inc.

Dosing Room with Aerosolized Challenge Agent

Pneumatic nebulizer “eSprayer”

Measured Air-Change Rates by Tracer Gas Decay

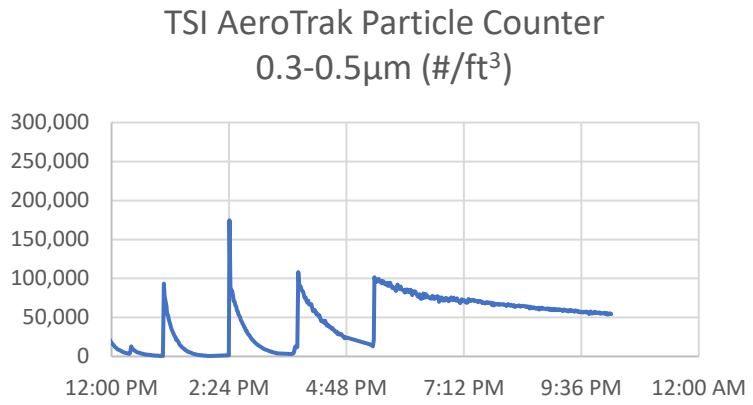


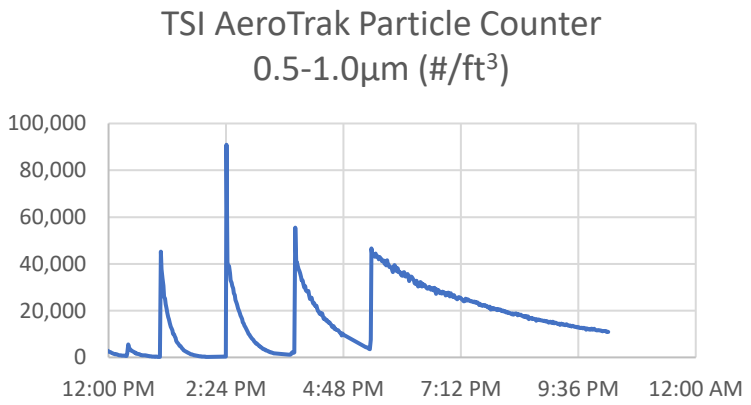
Calculated Air-Change Rates from supply-air diffuser CFM (k=1):

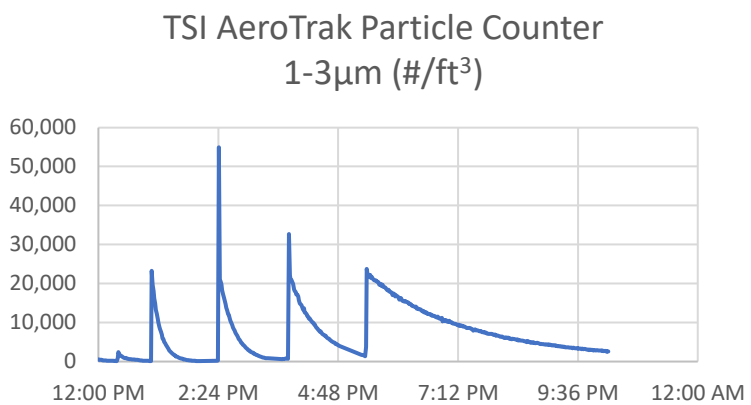
6 ACH	3.5 ACH	1.5 ACH	No mechanical ventilation

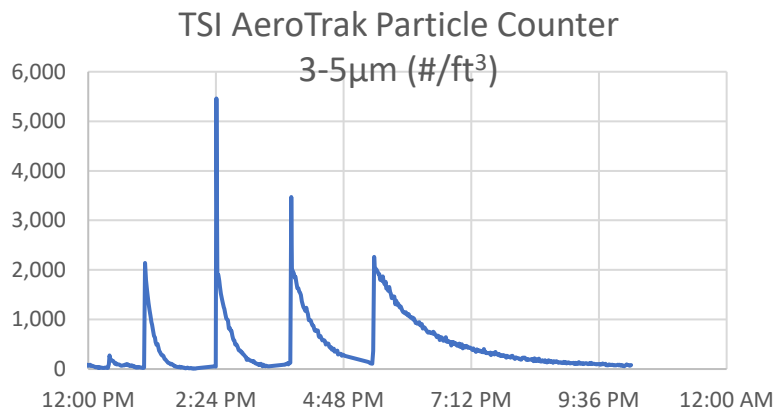
Measured Air-Change Rates by Size-Fractioned Aerosols

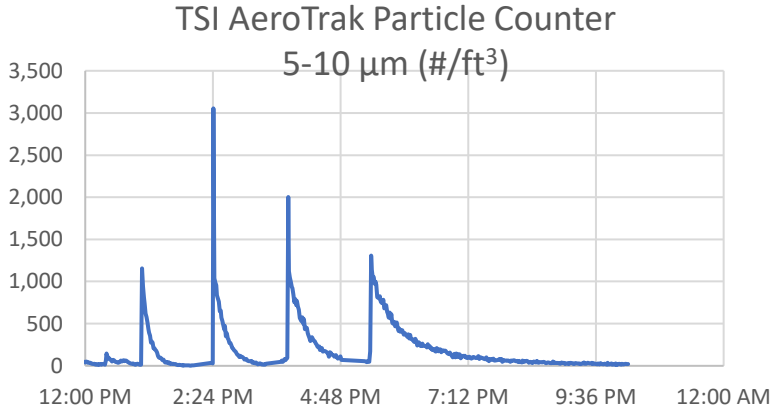
6 ACH	3.5 ACH	1.5 ACH	No mechanical ventilation

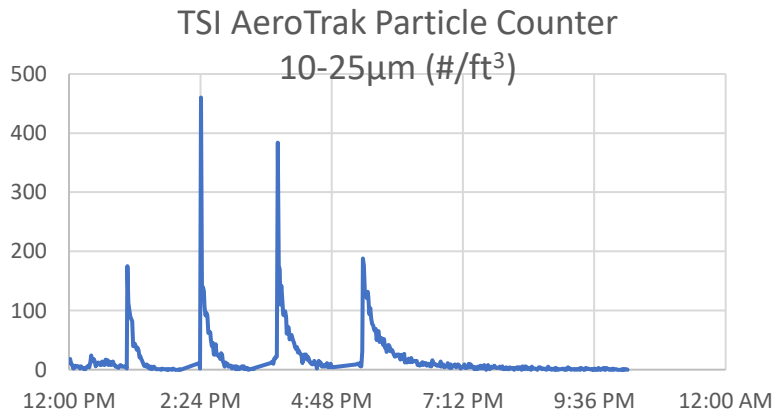








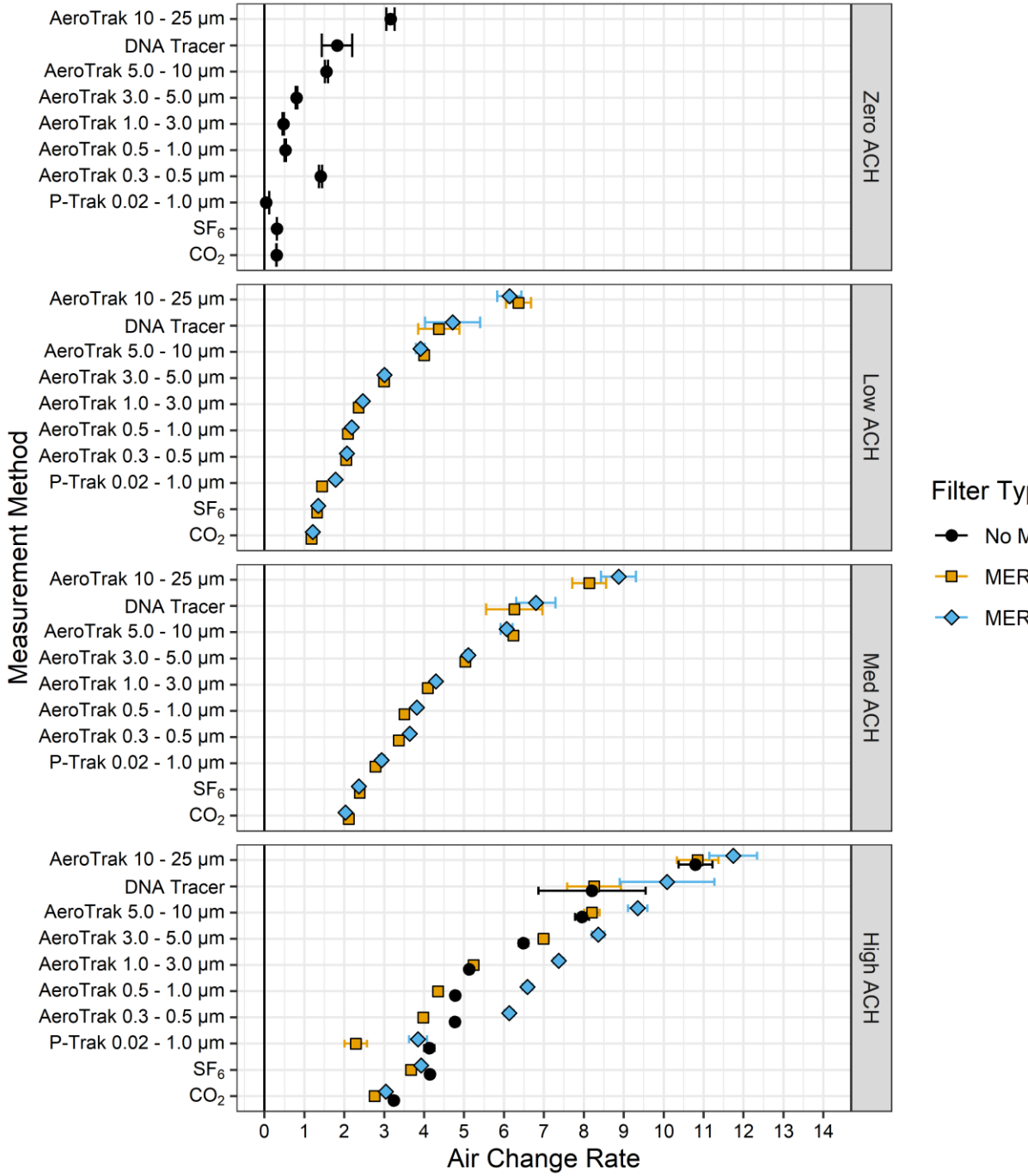




Results and Discussion

- Even with no ventilation, liquid aerosols concentration showed a decay of an equivalent 1.8 ACH.

- The decay rate of the DNA-tracer is like the fate of particles between 5-10 and 10-25 µm. The difference given the presence of the filter is not statistically significant.



Ventilation Study: Key Points

- Risk reduction can be estimated from calculated or measured rates of dilution ventilation and air filtration.
- Decay rates are different for gases and aerosols; especially when air filtration is present.
- Use of a DNA-tagged aerosol challenge agents allow for the direct measurement of building performance (and validation of risk reduction measures) with liquid aerosol particles in the size ranges relevant to SARS-CoV-2 risk assessment.

Ventilation Study: Findings

1. Calculation techniques may *overestimate* risk reduction from $ACH_{(OA)}$ because (k≠1).**

McDermott, Henry J. (2001). *Handbook of Ventilation for Contaminant Control*. ACGIH. 3rd Ed. Ch. 1.
"Good" air mixing, k = 1.5 to 2
"Fair" air mixing, k = 2 to 5
"Poor" air mixing, k = 5 to 10

2. Measurement techniques that use tracer gases may *underestimate* risk reduction as they measure dilution ventilation only; filtration matters.

3. Aerosol challenge methods provide the ability to measure the reduction of particle-size fractions relevant to infectious aerosols from dilution ventilation and filtration.

Call to Action / Current Needs

- We know: Ventilation plays an important role in managing indoor infectious aerosol transmission risk.
- Authoritative guidance calls for “more ventilation” but most guidance is loosely defined and non-quantitative.
- AIHA BTWS guidance documents have been embraced across many job sectors.
- Regulatory compliance angle.
  - e.g. OSHA Healthcare industry COVID-19 ETS

OSHA Healthcare Industry COVID-19 ETS

- Healthcare Industry specific ETS effective June 28, 2021
- Requires:
  - Employers to conduct a hazard assessment & implement COVID-19 plan
  - Provide and ensure employees wear facemasks, respirators, PPE under certain conditions
  - Physical distancing requirements
  - Ensure “adequate ventilation”, if the employer owns or controls the building.

What does this mean?!?

Final Thoughts

- Need to incorporate layered approach for effective risk management
- Ability to assess and control risk in occupied buildings with different techniques as scientific knowledge evolves
- Need to test, verify and validate control measures to reduce risk, document effectiveness, and demonstrate regulatory compliance
- Quantitatively measuring HVAC system performance is critical for understanding system deficiencies, implementing best practices and reducing COVID-19 aerosol transmission risk
- Aerosol challenge methods provide the ability to measure the reduction of particle-size fractions relevant to infectious aerosols from dilution ventilation and filtration.
- Proactive adoption of recommended guidance helps to reduce risk, limit liability, and facilitate safe work in occupied buildings.

California Industrial Hygiene Council

30th CIHC Professional Development Seminar

December 6-8, 2021 | Long Beach, CA

Thank You

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Consulting Health Scientists

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