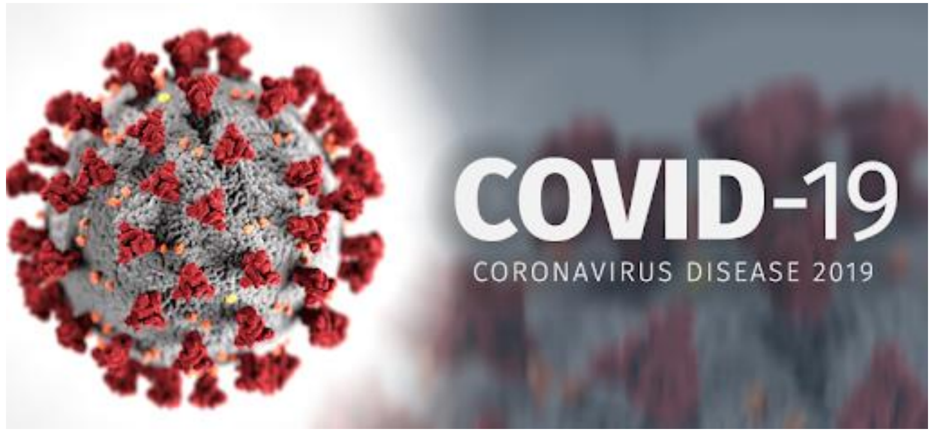
TOTAL. MECHANICAL

Building Integrity



EMC

Building Environment – Preparedness & Improvements

Introduction

<u>William A. Freeman</u>

- President at Safety/Environmental consulting firm of Environmental Management Consulting, Inc. (EMC).
- BS & MS in Occupational Safety from the University of Wisconsin-Whitewater.
- Certified Hazardous Materials Manger (CHMM)
- Certified Indoor Air Quality Professional (CIAQP)
- Served on the Board of Directors for the Wisconsin School Safety Coordinators Association (WSSCA) in the capacity of president and currently acts as an advisor to the board.
- Served as a Board of Directors for the Wisconsin Association of School Business Officials (WASBO).

Introduction

Benjamin N. Patterson

- Special Projects Manager at TOTAL Mechanical, Inc.
- Bachelor of Science in Architectural Engineering at the University of Milwaukee School of Engineering.
- Licensed Professional Engineer (PE) with the State of WI
- Has been directly involved in, or overseen, more than a hundred IAQ COVID response projects

TOTAL. MECHANICAL
Building Integrity

Introduction – CDC & ASHRAE

Centers for Disease Control & Prevention (CDC)

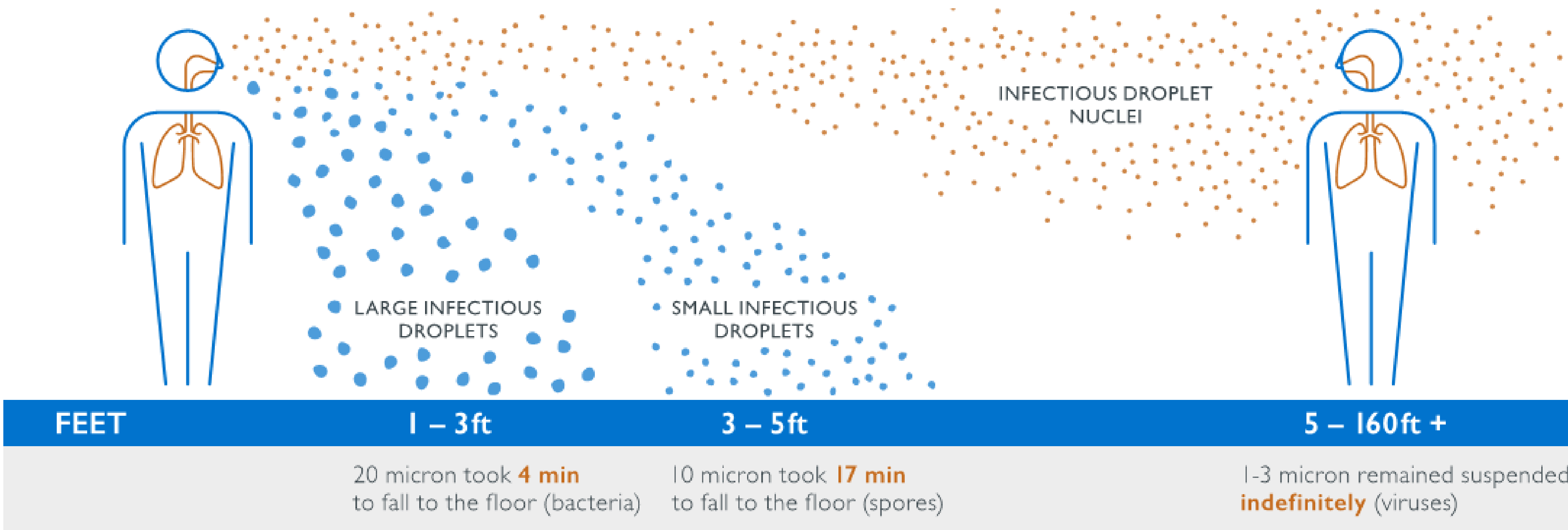
- US Federal Agency, under the Department of Health and Human Services, and is headquartered in Atlanta, Georgia.
  https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

- **Mission:** "To serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields."
- "State-of-the-art" design criteria
- Epidemic Task Force for Schools and Universities

  www.ashrae.org/covid19

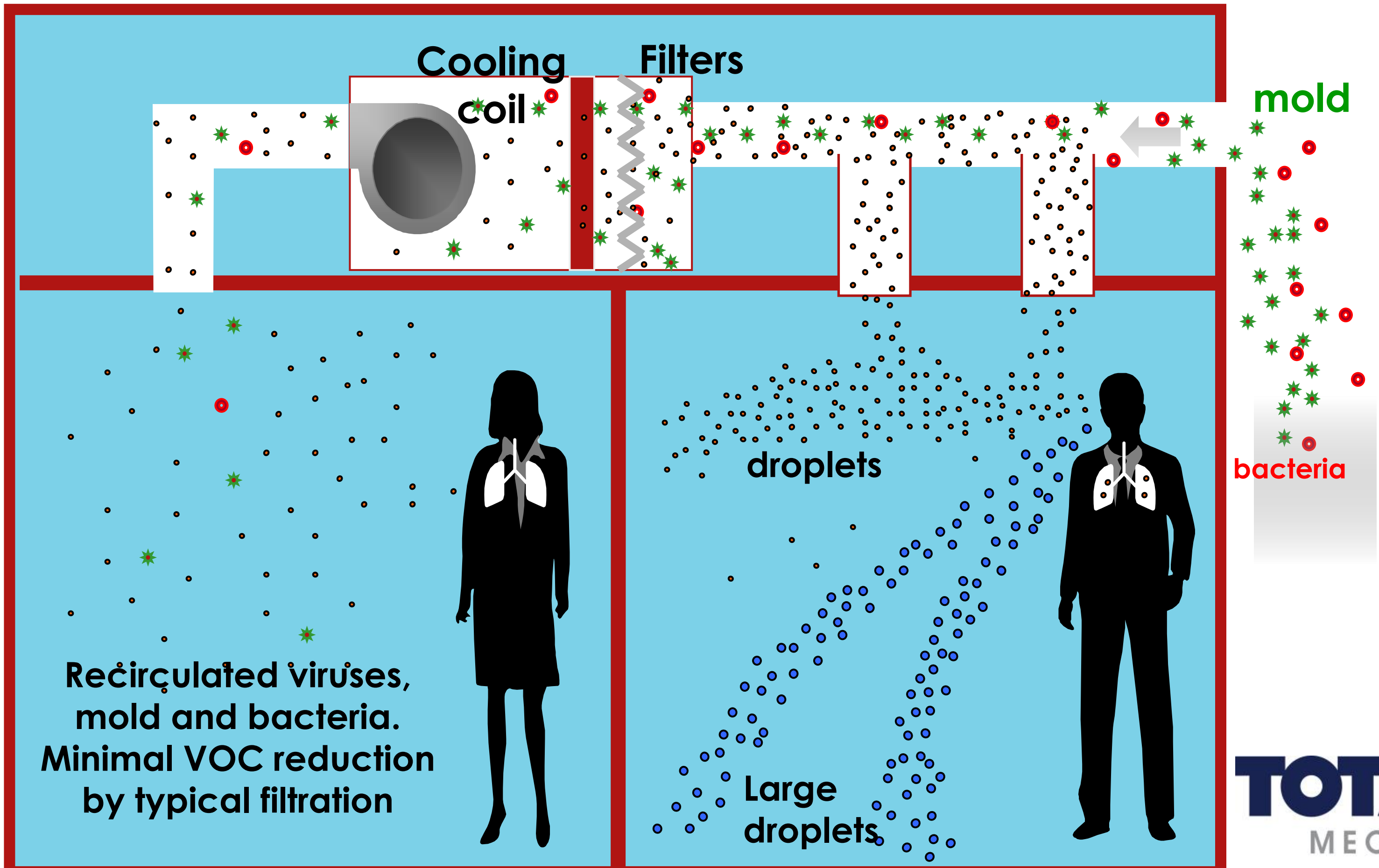
Aerosolized Risk [In Buildings]



J.W. Tang, Y. Li, I. Eames, P. K. S. Chan, G. L. Ridgway, Factors involved in the aerosol transmission of infection and control of ventilation in healthcare premises. Department of Microbiology, The Chinese University of Hong Kong, Prince of Wales Hospital. Hong Kong; Department of Mechanical Engineering, The University of Hong Kong, Pokfulam, Hong Kong; Department of Mechanical Engineering, University College London, London UK School of Public Health.

TOTAL. MECHANICAL
Building Integrity

Aerosolized Risk [HVAC Systems]

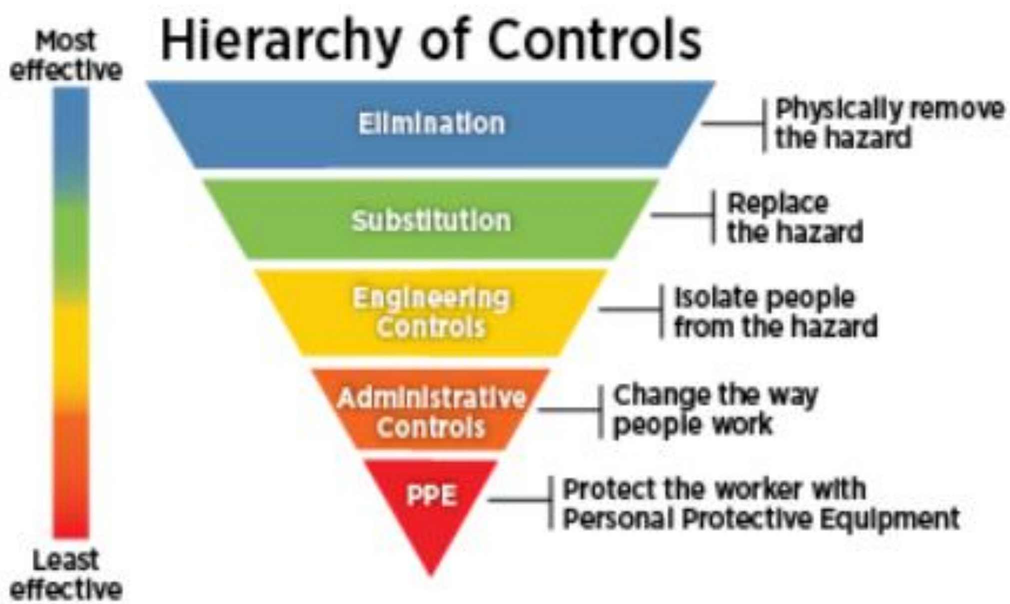


TOTAL. MECHANICAL
Building Integrity

OSHA Hierarchy Applied to IAQ

OSHA's Hierarchy of Controls

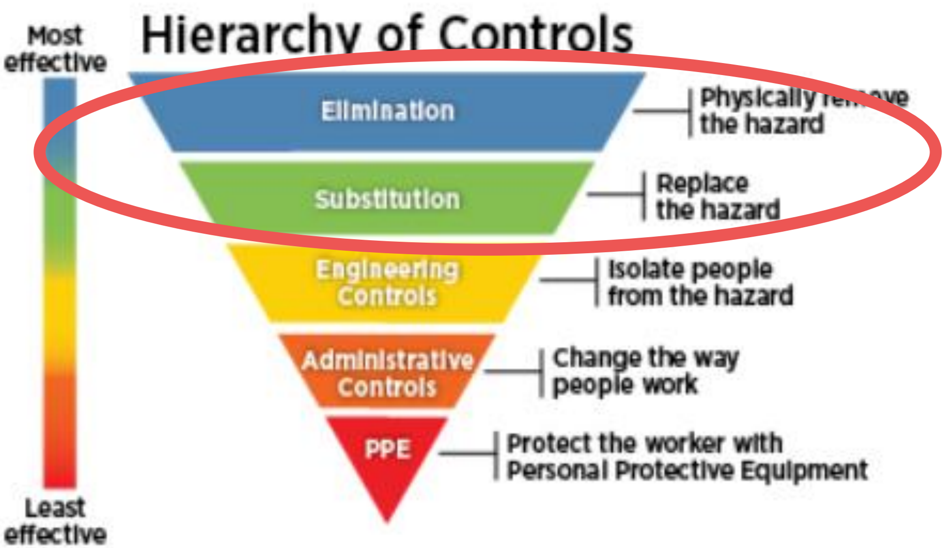
- Select the controls that are most feasible, effective, and permanent.



OSHA Hierarchy Applied to IAQ

Elimination & Substitution

- Shelter at Home
- Virtual Only Schooling
- Close businesses
- Close borders

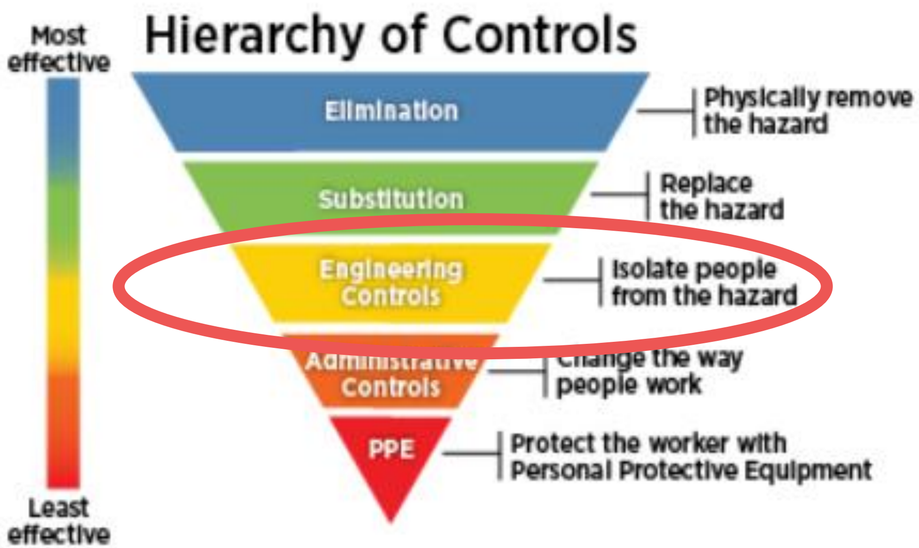


Very effective but not feasible for a long-term solution.

OSHA Hierarchy Applied to IAQ

Engineering Controls

- Building / HVAC Design
- HVAC Retrofit
- Ventilation (#1 Cause of IAQ Issues)
  - Preventative Maintenance
    - Ductwork Cleaning
    - HVAC Unit Cleaning
  - Filtration
  - Air Change
  - Carbon Dioxide (CO_2)
  - Ultraviolet Light Vs. Ionization Technologies



ASHRAE – Design Recommendations

General – Schools & Other Public Buildings

- Temp. & Humidity
  - Winter – 72F & 40%-50% RH
  - Summer – 75F & 50%-60% RH
    - Less humid air – viral droplets lose water content and become more aerosolized. This likely increases the rate of transmission.
- Ventilation Design Criteria/Guideline
  - Follow ASHRAE 62 for outside air requirements
  - During pandemic, disable any Demand Control Ventilation (DCV) and maximize outside air 24/7.
- Filtration Design Criteria/Guideline
  - Apply the highest Minimum Efficiency Reporting Value (MERV) for the HVAC units.
  - MERV 13 is recommended, if equipment can accommodate pressure drop.

TOTAL. MECHANICAL
Building Integrity

ASHRAE – Design Recommendations Continued

Operation & Scheduling Guidelines during Pandemic

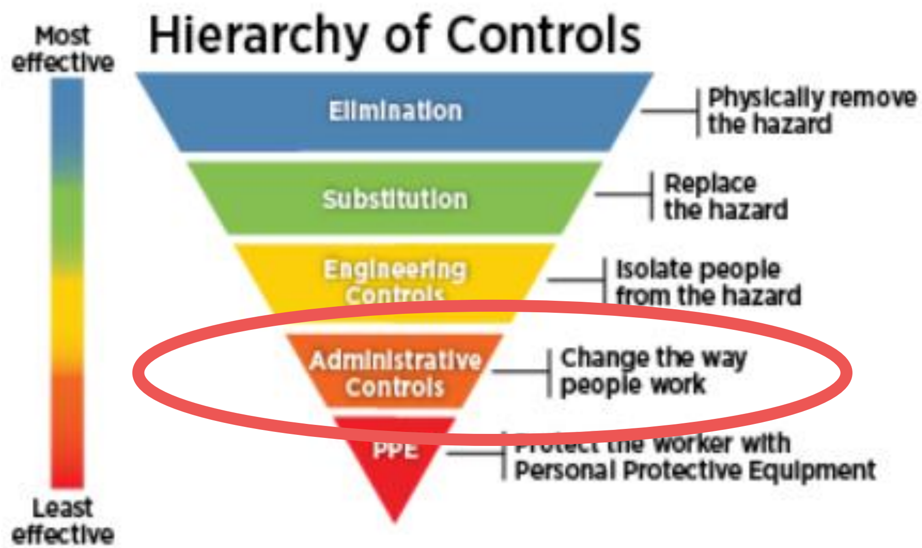
- Cooling & Heating Equipment
  - Change the start and end times to run at least 2 hrs before & after occupancy.
  - Consider running 24/7
- Exhaust Fans – Turn on when DOAS is running
  - Only school days
  - Goal is to flush the building with OA and create slight positive pressure.
- Dedicated Outdoor Air Systems (DOAS)
  - Run units 2 hrs before & after occupancy.
  - New units – "Purge/Flush" mode for operations to min. virus transmission.
- Energy Recovery Systems
  - Some systems allow for exhaust air transfer from the exhaust airstream to the supply airstream. Depending on system configuration, this may be cause for concern.
  - Discontinue use/forget everything you have learned about saving energy!

TOTAL. MECHANICAL
Building Integrity

OSHA Hierarchy Applied to IAQ

<u>Administrative Controls</u>

- IAQ Policies
- HVAC Policies
  - Ductwork Cleaning
- Cleaning Policies
- Social Distancing
- Contact Tracing
- Employee Awareness Training
- Real Time COVID-19 Testing of Students and Staff



Combination of Administration & Engineering Controls

Reduce Direct Contact Risks

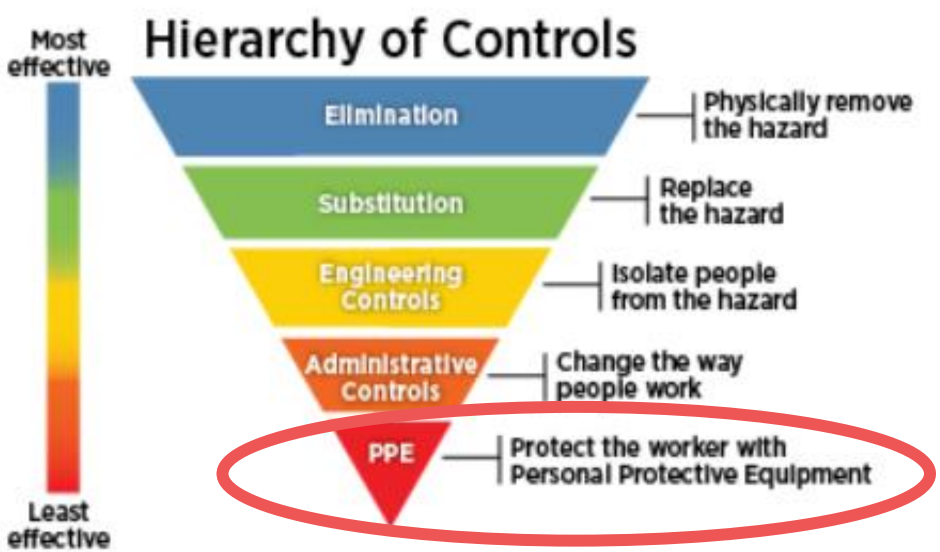
- Socially distance through setting up of A/B days, or A/B pods in school wings, screen & isolate infected people, etc.
- Add hand sanitizing stations to treat surface-to-hand transmission
- Clean common surfaces
  - Tables, doorknobs, light switches, handles, phones, keyboards, toilets, faucets, etc.
- Reduce contact through touchless devices

EMC

OSHA Hierarchy Applied to IAQ

<u>Personal Protective Equipment</u>

- PPE Policies
- OSHA Regulations
  - Use of Face-coverings Vs. N95

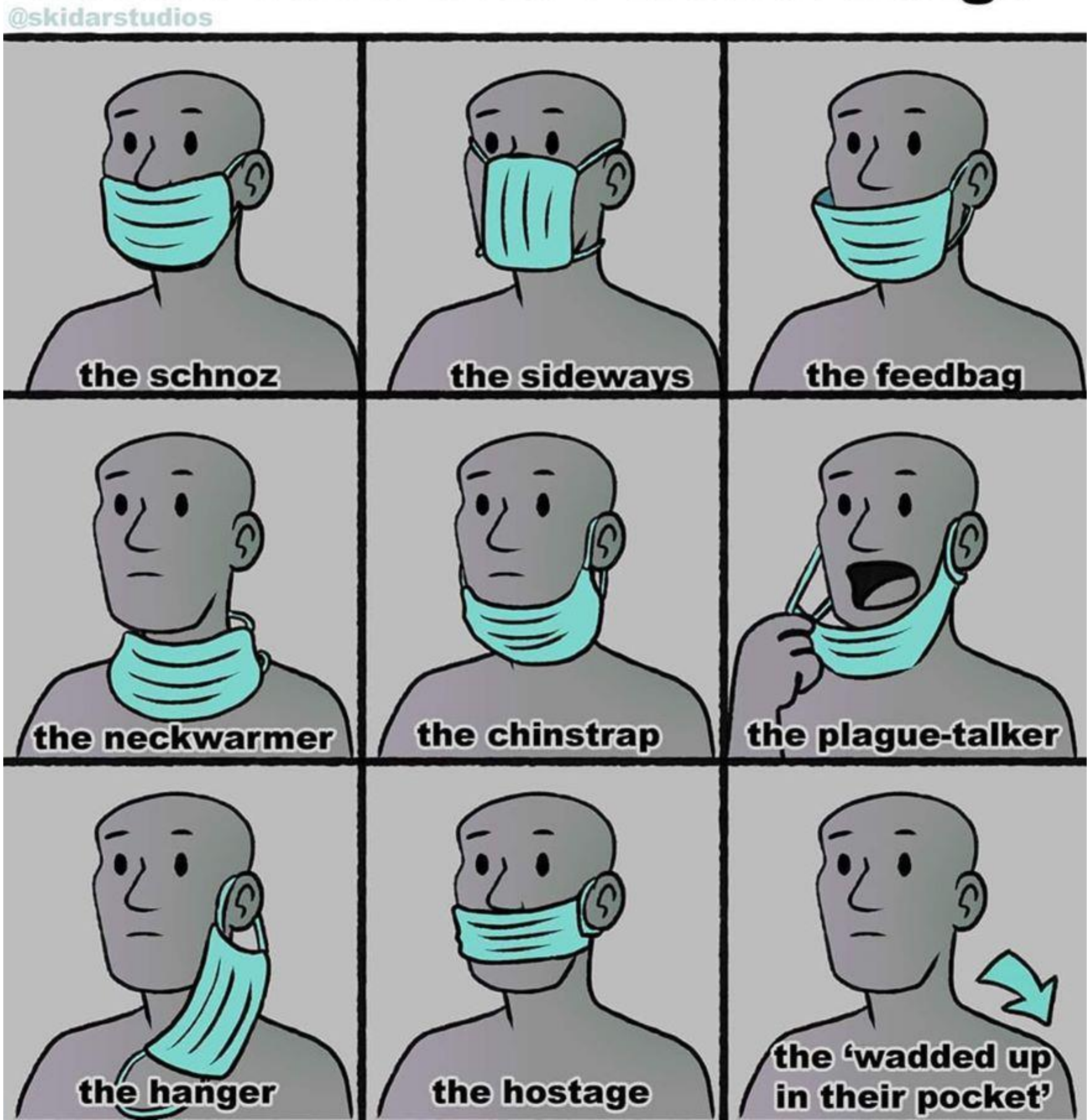


Personal Protective Equipment

Face-covering Recommendation from CDC

- General public - wear cloth face-coverings
- Healthcare setting – N95 and/or face-shield
- Currently, no specific guidance indicating that school employee are at higher risk than the general public.
- No OSHA Implications

Ineffective Face Mask Bingo



Personal Protective Equipment

N95 Respirator

- Can be used for "voluntary use" per OSHA regs.
  - Provide employee with OSHA Appendix D in 1910.134
- Supply of N95 respirators remains low and nationwide shortages may become worse if used by the general public.
- Not proper fit on children and people with facial hair.
- If mandated by employer, OSHA requires:
  - Employee Training
  - Medical Questionnaire reviewed by a Health Care Professional
  - Annual Fit Testing

A Closer Look at HVAC Engineering Controls

Treat Your Air: Evidence Based Methodologies

DILUTION

FILTRATION

ULTRAVOILET

IONIZATION

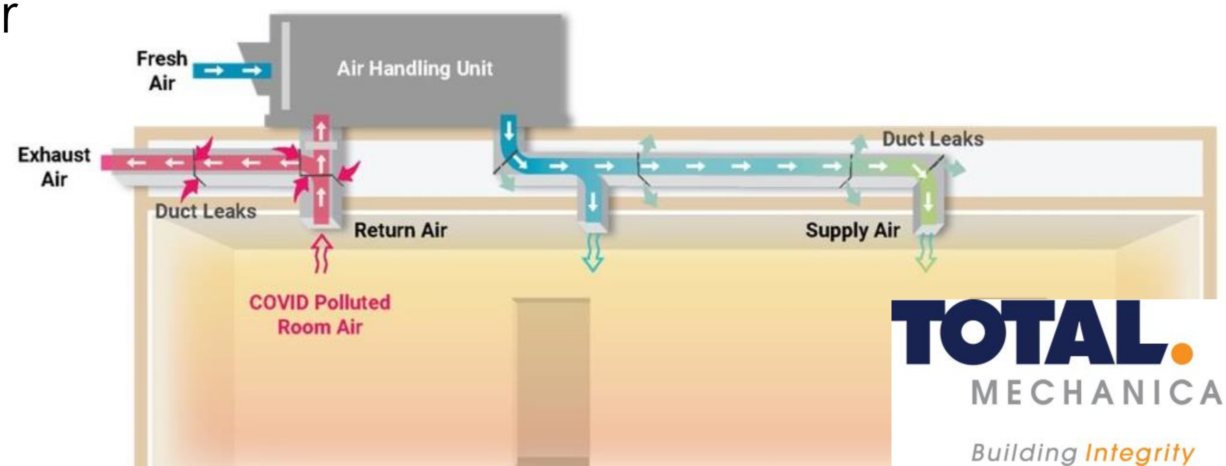
OTHER TECHNOLOGIES

TOTAL. MECHANICAL

Building Integrity

Dilution

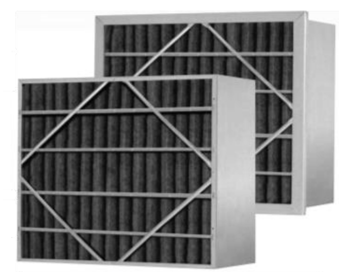
- Introduce additional clean air into your building so that the percentage of virus particles in your air (if a sick occupant is in the building) is decreased to reduce risk
- Seasonal impacts to your space (Winter/Summer)
- Utility cost impacts
- Maintenance cost impacts
- Equipment wear



TOTAL. MECHANICAL
Building Integrity

Filtration

MERV Rating	Air Filter will trap Air Particles size .03 to 1.0 microns	Air Filter will trap Air Particles size 1.0 to 3.0 microns	Air Filter will trap Air Particles size 3 to 10 microns	Filter Type ~ Removes These Particles
MERV 1	< 20%	< 20%	< 20%	Fiberglass & Aluminum Mesh
MERV 2	< 20%	< 20%	< 20%	~
MERV 3	< 20%	< 20%	< 20%	Pollen, Dust Mites, Spray
MERV 4	< 20%	< 20%	< 20%	Paint, Carpet Fibres
MERV 5	< 20%	< 20%	20% - 34%	Cheap Disposable Filters
MERV 6	< 20%	< 20%	35% - 49%	~
MERV 7	< 20%	< 20%	50% - 69%	Mold Spores, Cooking Dusts,
MERV 8	< 20%	< 20%	70% - 85%	Hair Spray, Furniture Polish
MERV 9	< 20%	Less than 50%	85% or Better	Better Home Box Filters
MERV10	< 20%	50% to 64%	85% or Better	~
MERV 11	< 20%	65% - 79%	85% or Better	Lead Dust, Milled Flour, Auto
MERV 12	< 20%	80% - 90%	90% or Better	Fumes, Welding Fumes
MERV 13	Less than 75%	90% or Better	90% or Better	Superior Commercial Filters
MERV 14	75% - 84%	90% or Better	90% or Better	~
MERV 15	85% - 94%	90% or Better	90% or Better	Bacteria, Smoke, Many
MERV 16	95% or Better	90% or Better	90% or Better	Viruses

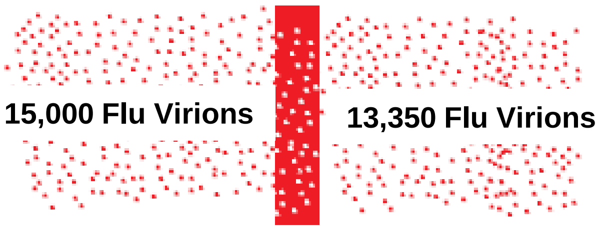




- Increased maintenance & utility costs
- Increased risk to equipment wear & facility worker exposure

TOTAL. MECHANICAL
Building Integrity

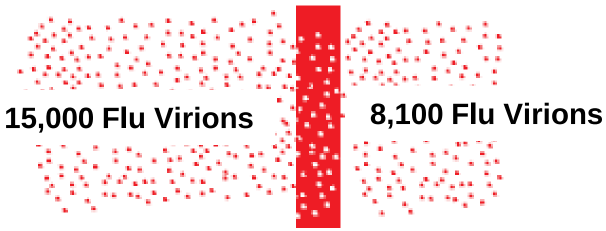
Filtration [Effect on Influenza A Virus]

MERV 8



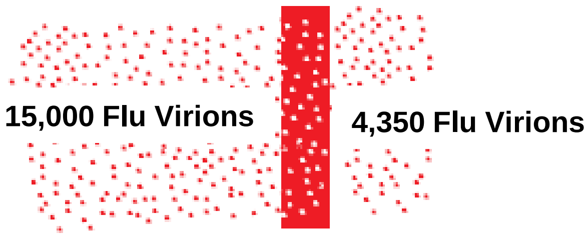
11% captured

MERV 13



46% captured

MERV 15



71% captured

HEPA*

HEPA is the most effective filter to remove virus particles

Source: Modeling Immune Building Systems for Bioterrorism Defense; Kowalski, Bahnfleth, Musser, Journal of Architectural Engineering, June 2003, v9(2), pp222-227.

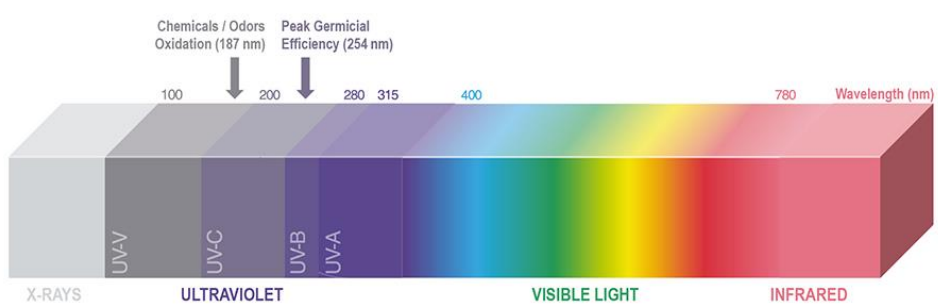
* HEPA was not part of the study above. It's a graphical representation of 99.97% efficiency HEPA filter (defined by DOE) with particulates in 0.3µm which is the toughest size to catch.

TOTAL. MECHANICAL

Building Integrity

Ultra-Violet

- UV lamps create high energy UV rays that scramble and destroy the viruses
  - UV-C band (at 254nm) are the most predominant used against bacteria & viruses



TOTAL. MECHANICAL
Building Integrity

Ultra-Violet [Effectiveness]

Common Name	Pathogenic name	Known, Published UVC value for pathogen reduction		FILTER EFFICIENCY		UVC-only Pathogen reduction/air pass	Pathogen reduction UVC + filtration
		UVGI K m^2/J	µw/cm^2	MERV 8	MERV 10	URV 11 1000µJ/cm^2 Coil Cleaning	MERV 11 + URV 11
Pneumonia	Pseudomonus aeruginosa	0.5721	0.005721	14	15	99.96%	99.99%
TB / Tuberculosis	Mycobacterium tuberculosis	0.4721	0.004721	19	21	99.85%	99.99%
Corona Virus	Caronavirus	0.3770	0.00377	18	20	99.45%	99.99%
Legionella	Legionella pneumophila	0.1930	0.0019298	15	16	93.00%	99.79%
Acinetobactor	Acinetobacter baumannii	0.1280	0.00128	42	44	82.86%	99.79%
Flu	Influenza A & B	0.1190	0.00119	30	31	80.60%	99.47%
Staph / MRSA	Staphylococcus aureus	0.1130	0.00113	28	30	78.93%	99.00%
Avian Flu	Avian Influenza Virus	0.1060	0.00106	12	13	76.79%	97.00%
Measles	Measles	0.1051	0.001051	10	9	76.50%	97.00%
Chicken Pox	Varicella Zoster	0.105	0.00105	10	9	76.47%	97.00%
Strep	Streptococcus pyogenes	0.8110	0.00811	29	31	99.99%	99.00%

Airborne Pathogen Reduction Rates at specific MERV filter + UVC Fixture ratings

TOTAL. MECHANICAL
Building Integrity

Ultra-Violet [Air Handling Units]

UVC Dose = Intensity x Exposure (dwell) Time
UVC energy is cumulative

Disinfection is accomplished by exposing a pathogen to:

High-intensity UVC energy for a **short time period**,
i.e 2000 µW for only 1 second

Low-intensity UVC energy for **long time period**,
i.e 20 µW for 100 seconds

NOTE: A 60W lamp is rated at 2047µW @ 7", or 200µW @ 38"

Air Disinfection vs. Surface Disinfection

Air moves through AHU at 500 f/m (@ 40° F)

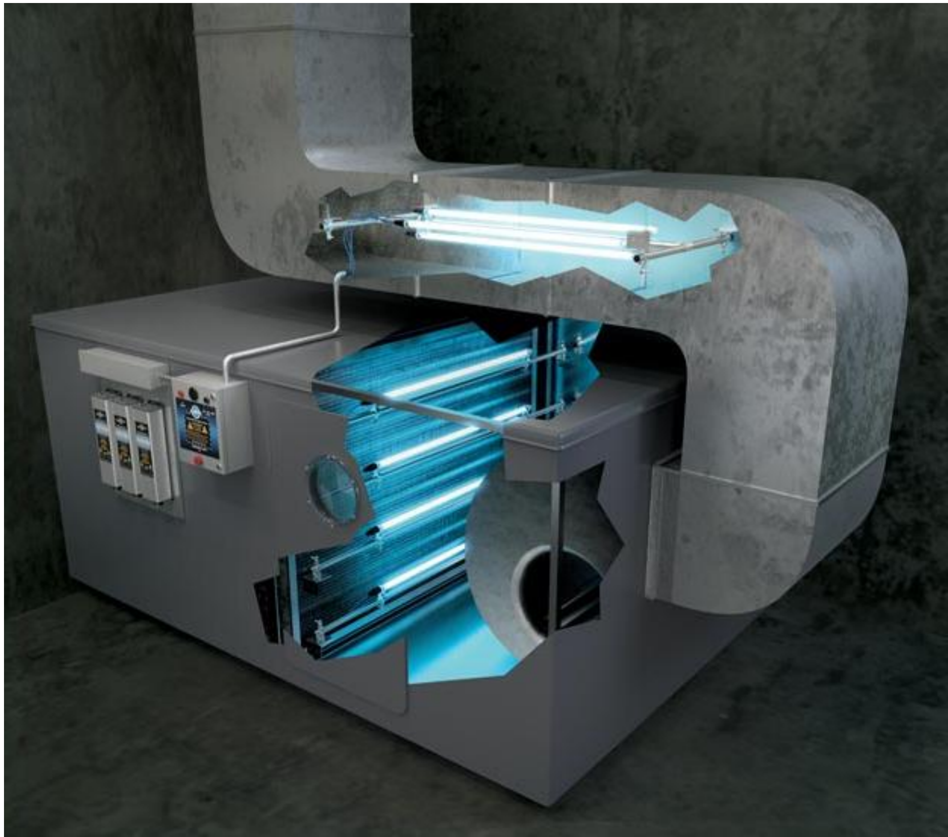
½ second moving air exposure

A high-intensity dose of UVC is required to achieve the desired level of disinfection. Therefore must generate 4000 µ to achieve 2000 µ intensity in ½ sec dwell time.

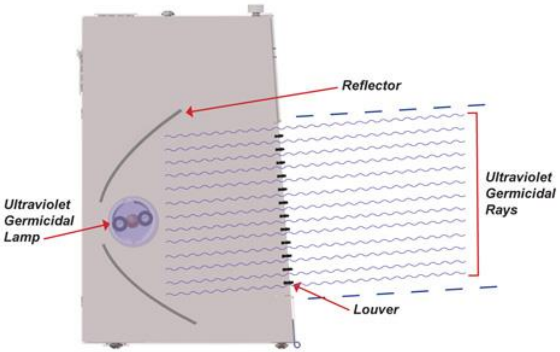
Contaminated cooling coil are stationary, and therefore receive

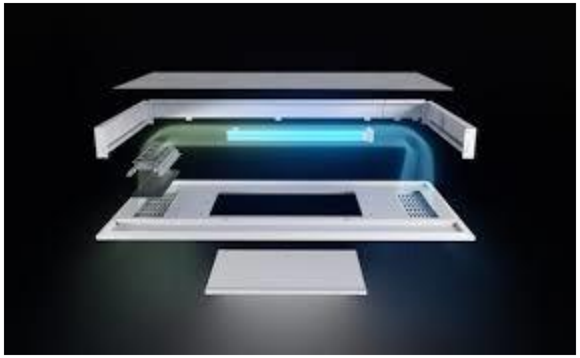
86,400 second surface exposure / 24 hours

A low-intensity dose of UVC energy is all that is required!



Ultra-Violet [In Space]





Ultra-Violet [Considerations]

+

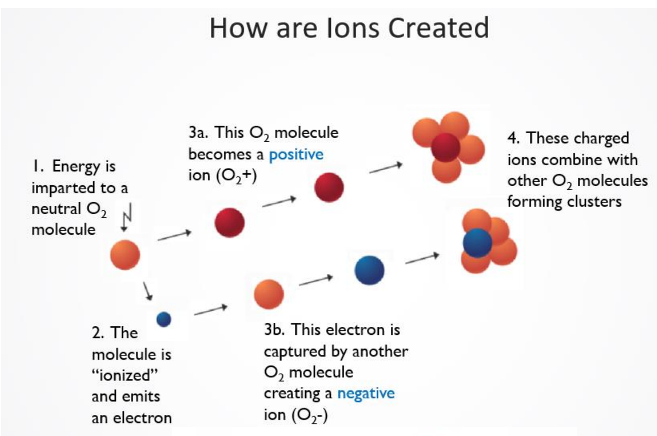
- Options for in room and in unit technologies
- Equipment protection from mold and mildew
- Quick kill of pathogens that are exposed to the light
- Long track record for medical use in virus & bacteria control

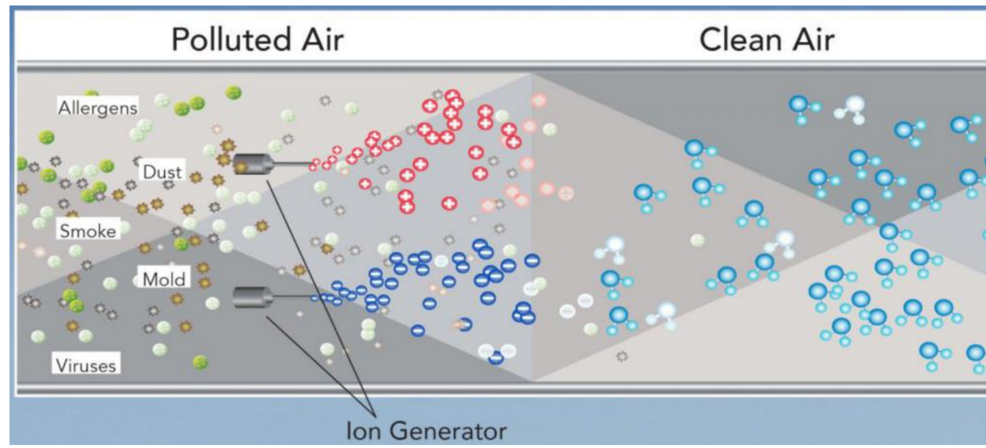
−

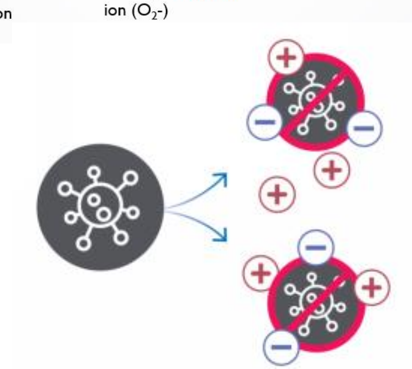
- Installation costs
- Equipment, electrical, install, reflective linings, safeties
- Increased utility costs
- Increased bulb replacement costs
- UV Lights will continue to glow and be "on" after effectiveness degrades (Replace 1-2 years per MFG.)
- Safety risks
- 12-24 week lead times

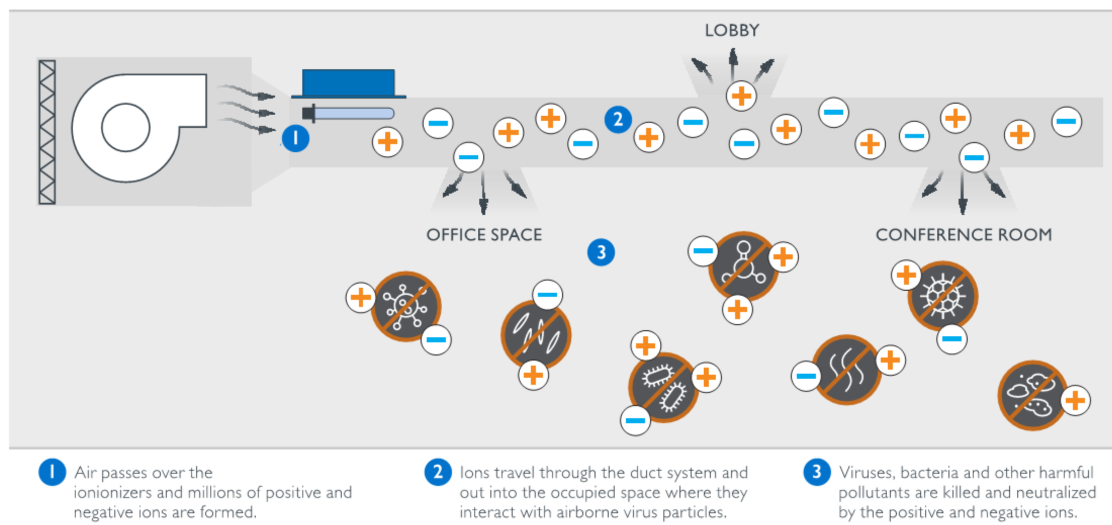
Ionization

- Ions attach to viruses to deactivate them, settle them, and agglomerate them









Ionization [Safety Considerations]

- Verify UL ratings for "Ozone Free" generation
  - (UL 2998) – Required under ASHRAE 62.1-2019 Section 5.7.1 for air purifiers applying to all UV, Ionizers, etc.

CHEMICAL	FORMULA	Electron Volt
Xylene*	C_8H_{10}	7.89
Styrene*	C_8H_8	8.46
Methyl Ethyl Ketone*	C_3H_8O	9.52
Ammonia*	NH_3	10.07
Acetaldehyde*	CH_3CHO	10.23
Ethyl Alcohol*	C_2H_5OH	10.48
Formaldehyde*	CH_2O	10.88
Oxygen	O_2	12.07
Corona tubes require >12.07 to break down the dielectric		

NPBI

DIELECTRIC/CORONA DISCHARGE TUBE > 12.07eV

* Typical contaminants of concern as contained within ASHRAE 62.1

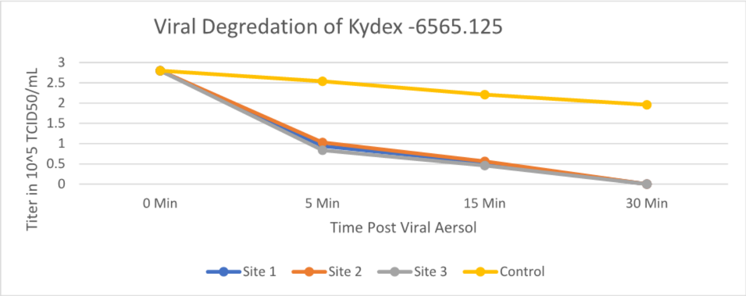
- Electron Volt Energy greater than 12Ev, creates ozone (O_3)

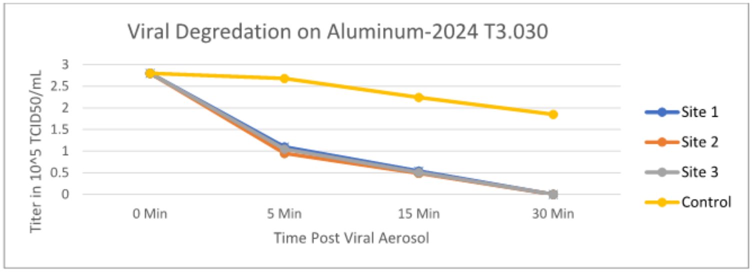
TOTAL. MECHANICAL

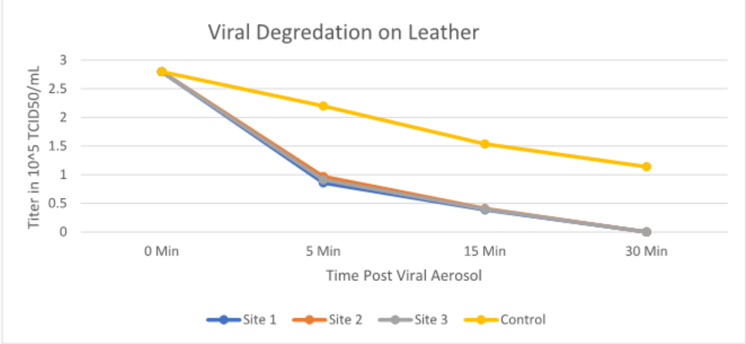
Building Integrity

Ionization [Effectiveness]

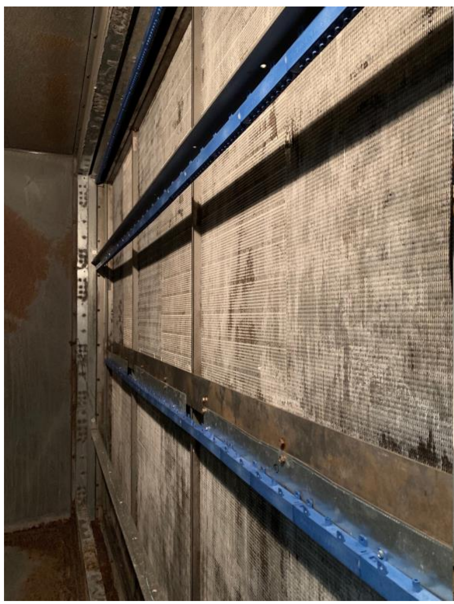
- Surface sample testing against SARS-CoV-2
  - 84.2% in 10 minutes
  - 92.6% in 15 minutes
  - 99.4% in 30 minutes
- Testing against other pathogens
  - E.Coli – 15 minutes – 99.68%
  - MRSA – 30 minutes – 96.24%
  - C. Diff – 30 minutes – 86.87%
  - TB – 60 minutes – 69.01%







Ionization [Options]



TOTAL. MECHANICAL

Building Integrity

Ionization [Considerations]

+

- Ions attach to viruses to deactivate them
- Options for in room and in unit technologies
- Tackles odors
- 4-6 week lead times

−

- Small increase on utility costs
- Time duration to kill pathogens
- Moderate installation costs
- Potential small maintenance costs

- Make sure your ionizers are UL listed to be free of ozone generation

TOTAL. MECHANICAL
Building Integrity

Ionization vs. UV Costs

1,500 CFM Unit Ventilator

Ionization

- Install price - $925
  - *Based on a NPBI unit with self-cleaning arms*
- Utility cost – $4.29/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $0
  - *Based on a self-cleaning ionization unit.*
- Replacement - $92.5/year
  - *Based on a linear plan to replace the unit at it's 10-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $1,892.90

Ultra-Violet Light

*Not available to retrofit into unit vents, pricing reflective of portable non-HEPA circulation unit

- Install price - $1,700
- Utility cost – $283.28/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $324/year
  - *Based quarterly filter replacement & yearly bulb replacement (labor by owner)*
- Replacement - $170/year
  - *Based on a linear plan to replace the unit at a 10-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $9,472.80

*Analysis is done in current dollars, no projection for inflation

TOTAL. MECHANICAL

Building Integrity

Ionization vs. UV Costs

Portable HEPA/UV/Ionizing Unit

- Purchase price- $4,071
  - *Based on a NPBI unit with self-cleaning arms*
- Utility cost – $986.45/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $423/year
  - *Based on quarterly pre-filter, yearly HEPA filter, and yearly UV bulb replacement (labor by owner)*
- Replacement - $264/year
  - *Based on a linear plan to replace the unit at it's 15-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $20,805.50

*Analysis is done in current dollars, no projection for inflation

TOTAL. MECHANICAL
Building Integrity

Ionization vs. UV Costs

Indoor 5,000 CFM AHU

Ionization

- Install price - $1,800
  - *Based on a NPBI unit with self-cleaning arms*
- Utility cost – $10.34/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $0
  - *Based on a self-cleaning ionization unit.*
- Replacement - $180/year
  - *Based on a linear plan to replace the unit at it's 10-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $3,703.40

Ultra-Violet Light

- Install price - $8,400
- Utility cost – $512.46/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $494/year
  - *Based on bi-yearly bulb replacement by owner (no labor costs included).*
- Replacement - $560/year
  - *Based on a linear plan to replace the unit at it's 15-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $24,064.60

*Analysis is done in current dollars, no projection for inflation

TOTAL. MECHANICAL

Building Integrity

Ionization vs. UV Costs

Indoor 15,000 CFM AHU

Ionization

- Install price - $5,300
  - *Based on a NPBI unit with self-cleaning distribution bar*
- Utility cost – $16.40/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $0
  - *Based on a self-cleaning ionization unit.*
- Replacement - $530/year
  - *Based on a linear plan to replace the unit at it's 10-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $10,764.00

Ultra-Violet Light

- Install price - $10,600
- Utility cost – $630.72/year
  - *Based on 24/7 operation, 12 cents per kWh, no demand charge*
- Maintenance - $519/year
  - *Based on bi-yearly bulb replacement by owner (no labor costs included).*
- Replacement - $707/year
  - *Based on a linear plan to replace the unit at it's 15-year life expectancy*

- Simple Ten Year Life Cycle Cost:
  - $29,167.20

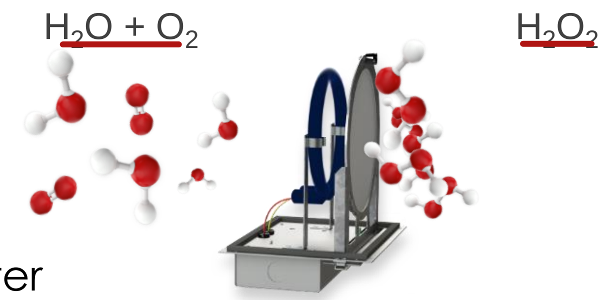
*Analysis is done in current dollars, no projection for inflation

TOTAL. MECHANICAL

Building Integrity

Other Technologies

- Dry Hydrogen Peroxide (Synexis)
  - Cleans air & surfaces
  - Newer technology
  - Requires weekly recharge, quarterly clean, filter changes, and UV bulbs



- Heated Filters (IVP)

- Far UV (222nm)

Summary

Holistic Approach to IAQ

- Complete what is feasible in a timely manner
  - You can't complete everything overnight
- Develop a short and long term IAQ Plan
- Dilution/Filtration/UV Light/Ionization are one piece of the puzzle
  - Done in cooperation with Administrative and Engineering controls as well as PPE to reduce overall viral load long after a pandemic

Measuring Success

- IAQ assessments prior to and after the installation of engineering controls
  - LEEDS-CO, CO2, PM10, TVOC's, Formaldehyde
  - Surface/Air sampling for SARS-CoV-2 (Covid-19)
    - Qualitative (presence/Absence)

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THANK YOU!

TOTAL.
MECHANICAL
Building Integrity

EMC