Mitigating Pathogen Transmission

Part Two: Humidification / Ultraviolet Germicidal Irradiation / Ionization

Presenter:
Dan Hahne (Varitec, Senior Sales Engineer)

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SOLUTIONS

Introduction

- Education:
  - University of Arizona – Chemical Engineering
    - 1974 thru 1976
  - University College London – BFA Degree (Sculpture)
    - 1978 thru 1983
  - Boston University – MFA Degree (Sculpture)
    - 1983 thru 1985

Industry:

- Norman S. Wright SW: Estimator/Sales
  - 1985 thru 1999
- Air Specialty Products/ThermAir Systems – Outside/Engineering Sales
  - 2000 thru 2008
- **Varitec Solutions:**
  - Senior Sales Engineer/Educator (High Performance HVAC)
  - 2016 thru present

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Acknowledgements

Presentation Material by:

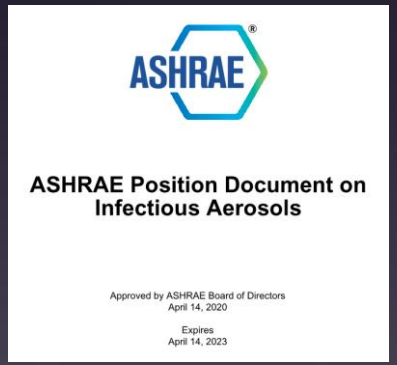
- ASHRAE – Epidemic Task Force
- driSteem
  - (Compiled by John Rees)
- UV Resources
  - (Provided by UV Resources)
- Global Plasma Solutions
  - (Provided by GPS)

Agenda

- Part One: Review
- Humidification
- UV Light Technology
- Ionization

Part One: Review

ASHRAE Epidemic Task Force: (www.ashrae.org)



Resource for latest information:

- ASHRAE Position Document on Infectious Aerosols
- Guidance for:
  - Reopening
  - Buildings
  - Filtration/Disinfection
  - Transportation
  - Resources

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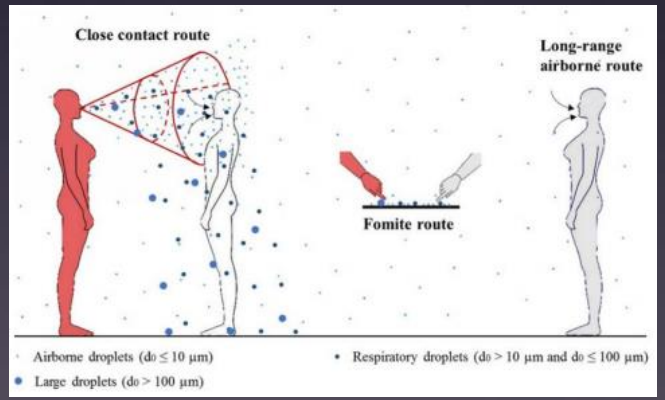
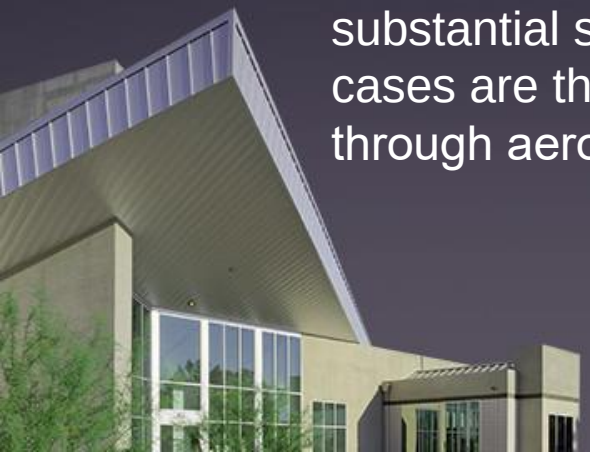
Part One: Review

TIME Article by Professor Jose-Luis Jimenez

COVID-19 Is Transmitted Through Aerosols. We Have Enough Evidence, Now It Is Time to Act

To challenge the WHO and CDC, Dr. Jimenez wrote: “I…believe that a substantial share of COVID-19 cases are the result of transmission through aerosols.”





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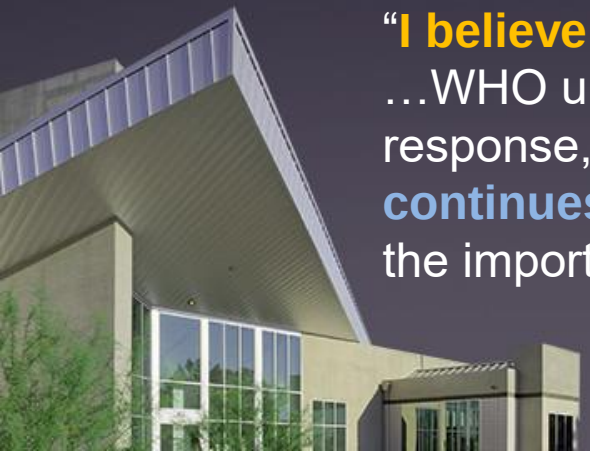
Part One: Review

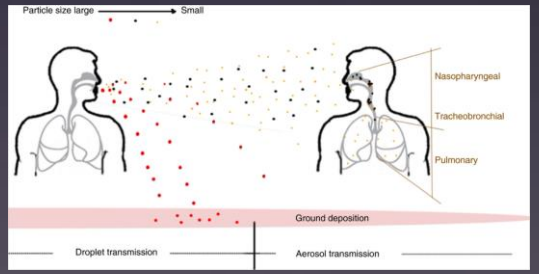
TIME Article by Professor Jose-Luis Jimenez

COVID-19 Is Transmitted Through Aerosols. We Have Enough Evidence, Now It Is Time to Act

- Regarding the WHO & CDC's not adequately addressing the transmission of SARS-CoV-2 as an aerosol:



"**I believe this is a significant mistake** …WHO updated their position in response, but the agency's language **continues to express skepticism** of the importance of this pathway."



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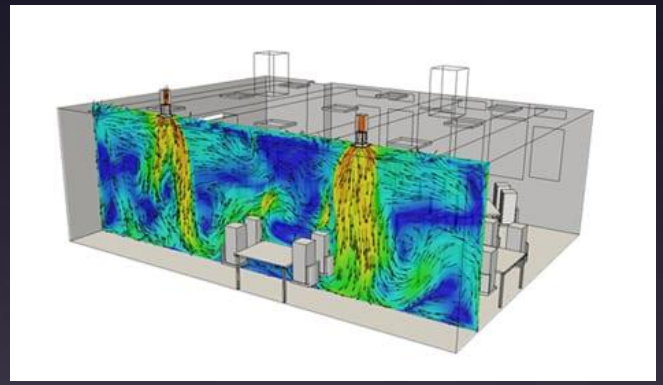
Part One: Review

ASHRAE Epidemic Task Force:

ASHRAE Issues Statements on Relationship Between COVID-19 and HVAC in Buildings

Media Contact:
Sherri Simmons
404-446-1660
ssimmons@duffey.com

ASHRAE COVID-19 Resources (ashrae.org/covid19)



"Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air."

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Part One: Review

Center for Disease Control (CDC)

Updated October 5, 2020

COVID-19 can sometimes be spread by airborne transmission

- Some infections can be spread by exposure to virus in small droplets and particles that can linger in the air for minutes to hours. These viruses may be able to infect people who are further than 6 feet away from the person who is infected or after that person has left the space.
- This kind of spread is referred to as **airborne transmission** and is an important way that infections like tuberculosis, measles, and chicken pox are spread.
- There is evidence that under certain conditions, people with COVID-19 seem to have infected others who were more than 6 feet away. These transmissions occurred within enclosed spaces that had inadequate ventilation. Sometimes the infected person was breathing heavily, for example while singing or exercising.
  - Under these circumstances, scientists believe that the amount of infectious smaller droplet and particles produced by the people with COVID-19 became concentrated enough to spread the virus to other people. The people who were infected were in the same space during the same time or shortly after the person with COVID-19 had left.
- Available data indicate that it is much more common for the virus that causes COVID-19 to spread through close contact with a person who has COVID-19 than through airborne transmission. [1]

COVID-19 spreads less commonly through contact with contaminated surfaces

- Respiratory droplets can also land on surfaces and objects. It is possible that a person could get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or eyes.
- Spread from touching surfaces is not thought to be a common way that COVID-19 spreads

CDC acknowledges airborne transmission for spreading the virus

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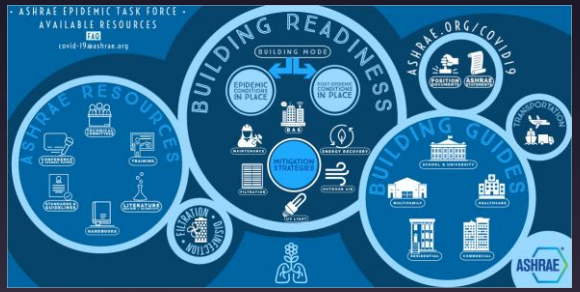
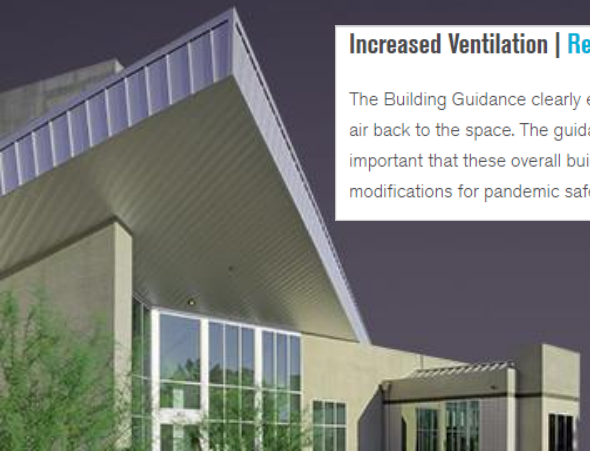
Part One: Review

ASHRAE Epidemic Task Force: Dilution

- Building Readiness: Outdoor Air
- ASHRAE's Position Document on Infectious Aerosols





Increased Ventilation | Return to Top

The Building Guidance clearly encourages building operators to increase their systems **outdoor air ventilation** to reduce the recirculation air back to the space. The guidance indicates that this must be done as much as the system and or space conditions will allow. It is very important that these overall building systems are evaluated by a qualified TAB firm, Cx provider or design professional to ensure that the modifications for pandemic safety do not create additional issues.

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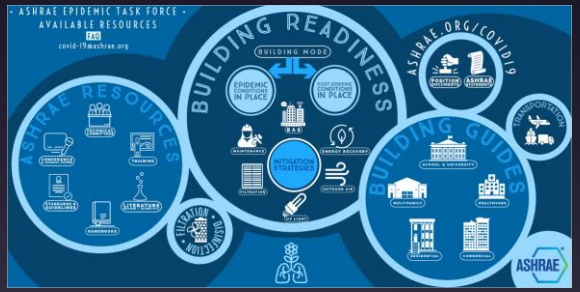
Part One: Review

ASHRAE Epidemic Task Force: Dilution



- Increased OSA air changes per hour:
  - The Building Guidance clearly encourages building operators to **increase their systems outdoor air ventilation** to reduce the recirculation air back to the space
    - The guidance indicates that this must be done as much as the system and or **space conditions will allow.**

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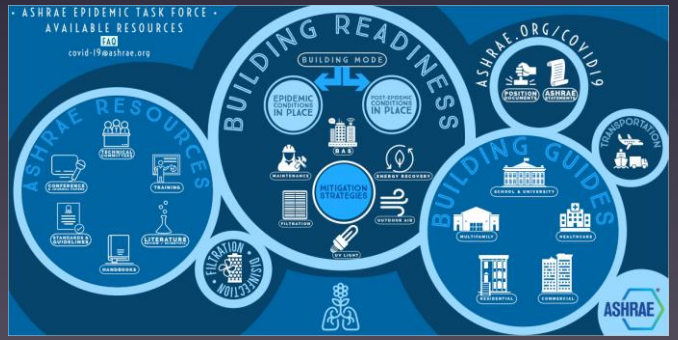
Part One: Review

ASHRAE Epidemic Task Force: Filtration

- Air Filtration:
  - Efficiency Standards
  - MERV Ratings



- MERV Ratings:
  - MERV ranges from 1 to 16: Higher MERV = higher efficiency
  - MERV 13 or greater: Efficient @ capturing airborne viruses
  - MERV 14: Preferred
  - High Efficiency particulate air (HEPA) filters

FILTRATION

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Part One: Review

ASHRAE Epidemic Task Force: Filtration

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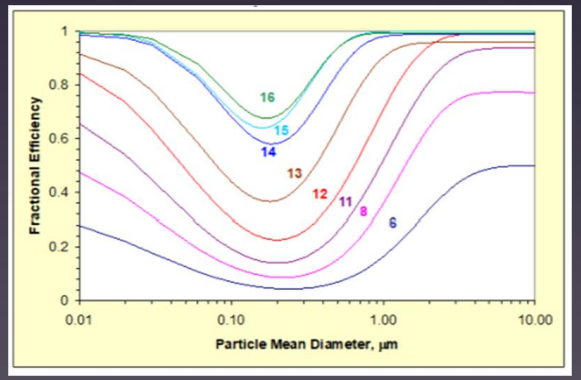
  - Efficiency Standards
  - MERV Ratings



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FILTRATION

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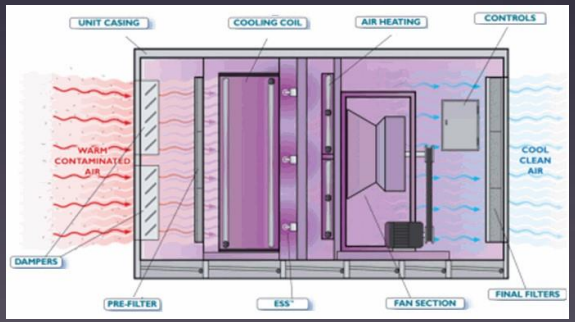
Part One: Review

ASHRAE Epidemic Task Force: Filtration

- Design Consideration:
  - “Increased filter efficiency generally results in increased pressure drop through the filter. Ensure HVAC systems can handle filter upgrades without negative impacts to pressure differentials and/or air flow rates prior to changing filters”.

Increase in fan motor HP will require higher electrical demand. Is additional electrical service available?



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Questions?

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Humidification

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Humidification

- Proper Space Humidification
  - ASHRAE and Related Humidification Studies
  - The role of humidity in airborne transmission of viruses
  - The impact of humidity on human health
  - Employing humidification to help reduce the spread of viral and bacterial pathogens

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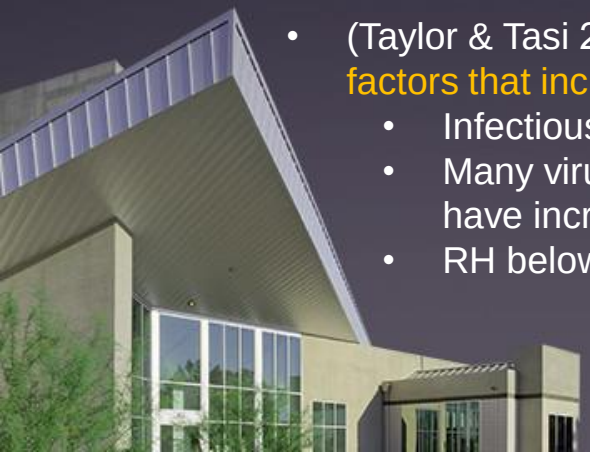
Humidification

ASHRAE Position Document on Infectious Aerosols

Section 3.3: Temperature & Humidity

References:

- (Taylor & Tasi 2018): "…the weight of evidence…suggests that controlling RH reduces transmission of certain airborne infectious organisms…this position document encourages designers to give careful consideration to temperature and RH.
- Mousavi et al. (2019): "…scientific literature reflects the most unfavorable survival for microorganisms when the RH is between 40% and 60%.
- (Taylor & Tasi 2018): "These studies showed that RH below 40% is associated with three factors that increase infection:
  - Infectious aerosols emitted from a primary host shrink rapidly to become droplet nuclei.
  - Many viruses and bacteria are anhydrous resistant (survive in dry environments) & have increased viability in low-RH conditions
  - RH below 40% impairs mucus membrane barriers in immune system protection



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Humidification

The notion that humidification levels reduce the transmission of viruses, bacteria, and allergens is not new. Studies have proven this over and over again:

1986 – Arundel et al.- Indirect health effects of relative humidity in indoor environments

2007- Lowen et al.- Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature

2012 – Noti et al- Detection of Infectious Influenza Virus in Cough Aerosols Generated in a Simulated Patient Examination Room

2012 – Yang, Marr- Mechanisms by Which Ambient Humidity May Affect Viruses in Aerosols

2013 – Welty- Airborne Influenza in Dry Wintertime Indoor Air: Is 50% RH Indoor Humidity One Cure for “Flu Season”?

2018 - Reiman et al.- Humidity as a non-pharmaceutical intervention for influenza A

2019 – Iwasaki et al.- Low ambient humidity impairs barrier function and innate resistance against influenza infection

2020 – Van Dormelen- How Long Will Coronavirus Live on Surfaces or in the Air Around You?

2020 - Gough- Humidity helps in the fight against COVID-19, virologists report

2020 - Wei Luo- The role of absolute humidity on transmission rates of the COVID-19 outbreak

Yale

MAYO CLINIC

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

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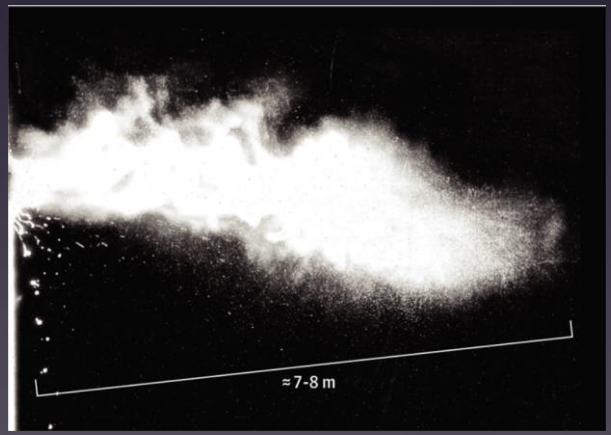
Humidification

Aerosolization:

- The process or act of converting some physical substance into the form of particles small and light enough to be carried on the air, i.e. into an aerosol (Wikipedia)

Researchers have captured pathogen bearing aerosols travelling up to **25 feet** from a simple sneeze.

Factors influencing travel and evaporation include temperature and relative humidity.



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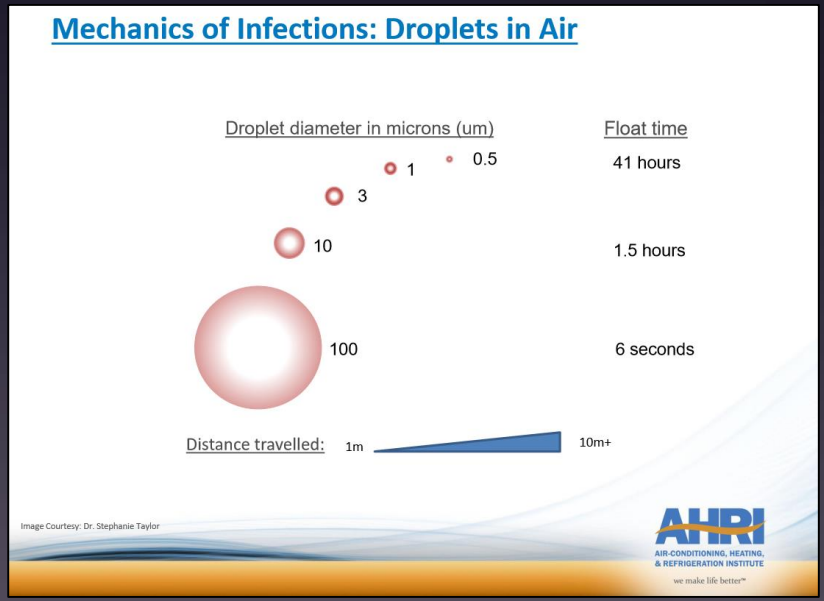
Aerosolization & Precipitation:
Droplet Size, Buoyancy & Float Time

- Droplets: by definition larger than **20 microns**
- Small droplets and aerosols: range from **10-20 microns**
- Droplet nuclei: Below 10 microns (may be **0.5 microns or smaller**)



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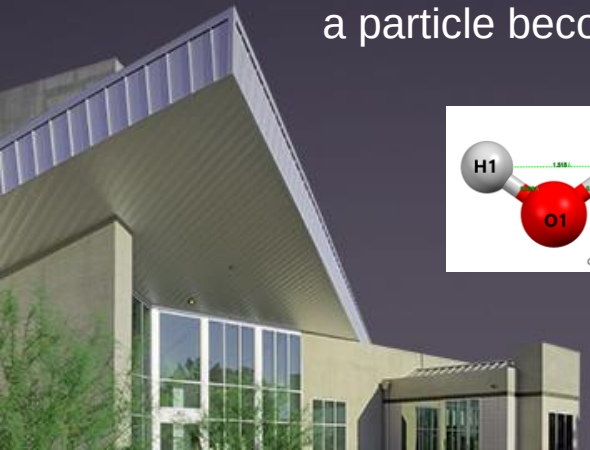
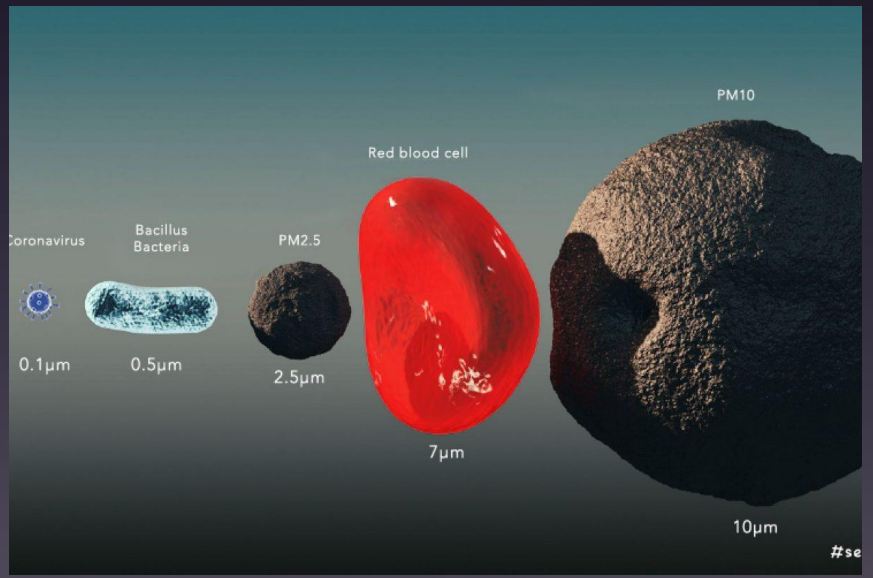
Aerosolization & Precipitation:
Droplet Size, Buoyancy & Float Time

SARS-CoV-2 = ~0.125 microns

- Low Humidity desiccates the virus; i.e. H20 molecules are decoupled from pathogen
- Less mass the more buoyant a particle becomes





H_2O molecule = .000275 microns

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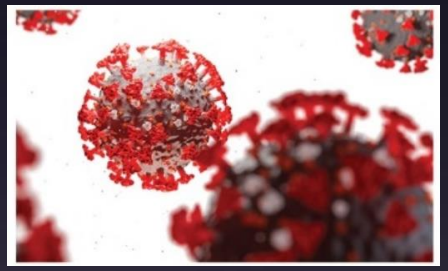
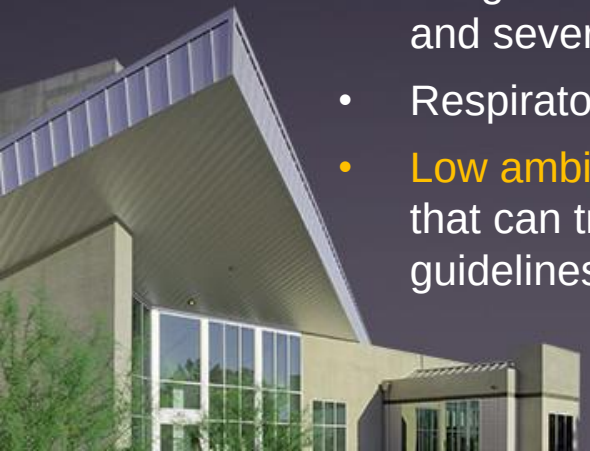
Aerosolization & Precipitation:
Droplet Size, Buoyancy & Float Time

Airborne viruses are expelled as aerosols (tiny droplets) by breathing, speaking, singing, coughing and sneezing.



- COVID-19 behaves similarly to SARS (SARS Cov-1), MERS and H1N1 (Influenza) as an aerosol
- Length of time virus is airborne and distance traveled affects spread and severity of infection.
- Respiratory viruses are most harmful when inhaled deep into the lungs.
- Low ambient humidity causes aerosols to desiccate into virus nuclei that can travel long distances (beyond our 6 ft. social distancing guidelines).



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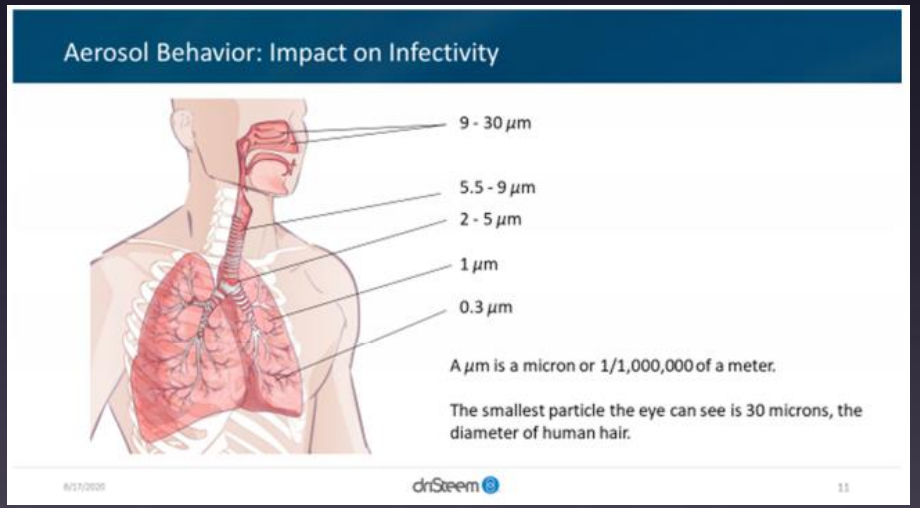
Humidification

Aerosolization & Ingestion:

- Aerosolized pathogen more readily bypass the body's natural defense systems and travel deep into the lungs reducing the immune system's chances of fighting the virus



ASHRAE Position Document on Infectious Aerosols

- (Kudo 35 al. 2019) "…immunobiologists have now clarified the mechanisms through which ambient RH below 40% impairs mucus membrane barriers and other steps in immune system protection."

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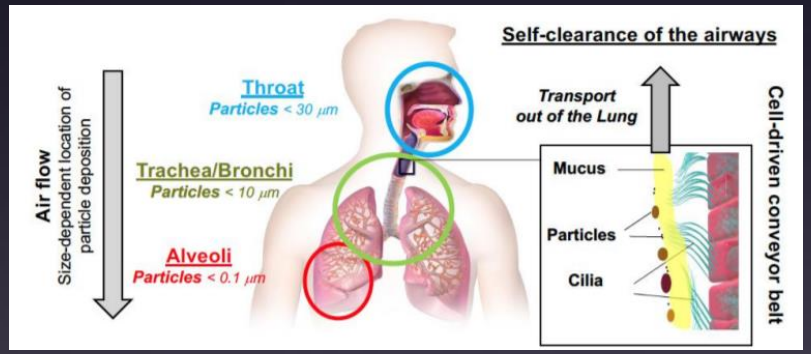
Humidification

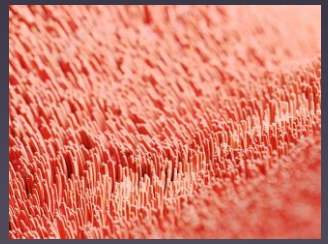
Aerosolization & Ingestion:



Self-Clearance Mechanism of the Lung

- Nature developed a powerful mechanism to self-clean the airways: their **cellular linings operate as conveyor belts.**
- Inhaled particles collide with the airway walls where they get stuck on slimy surfaces.
- The prevalent location where inhaled particles get deposited along the airways depends on the particle size.

- The particle-enriched slime, including virus particles, is transported towards the mouth through synchronized circular movements of cilia.



(Cilia)

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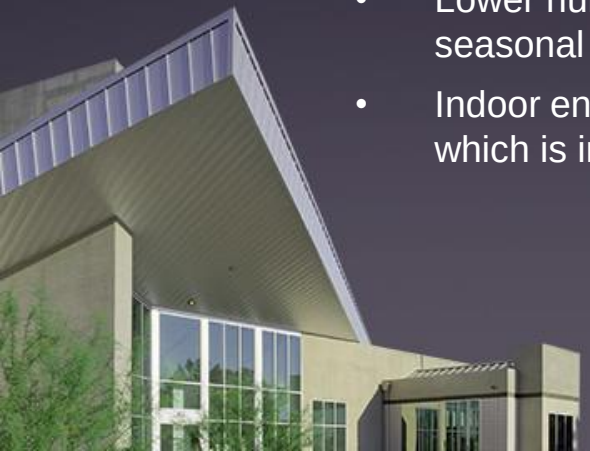
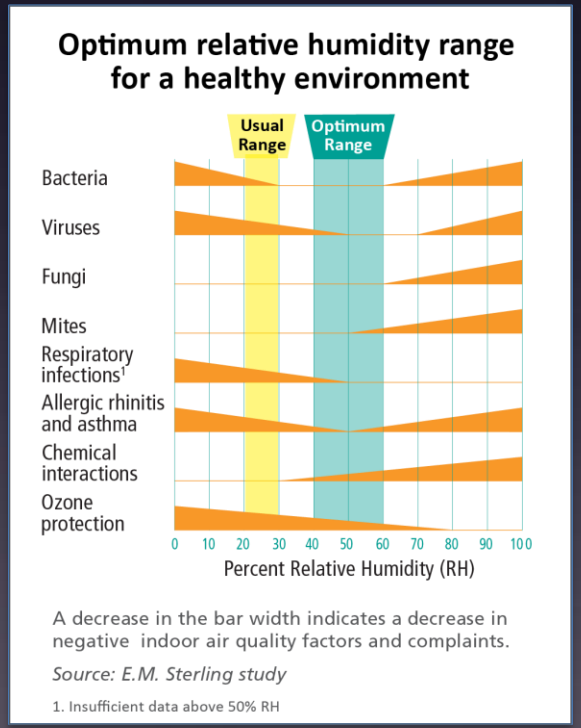
Humidification

The Sterling Study (1986): 013 ASHRAE Paper

Optimum range for health, wellness and comfort:
40 - 60% RH

- Lower humidity increases survival for viruses that cause respiratory infections
- Lower humidity increases allergens that cause seasonal allergies and asthma
- Indoor environments are usually 20 - 30% RH, which is inadequate for protection





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Humidification

Steven Welty: 2013 ASHRAE Paper

2013 (2009) - Airborne Influenza in Dry Wintertime Indoor Air: Is 50% RH Indoor Humidity One Cure for "Flu Season"?

- In 2013, Steven Welty presented a paper to ASHRAE based on his earlier research for the EPA/CDC in 2009 following the H1N1 Flu Pandemic.
- Yes, H1N1 was classified as a Pandemic back then by the CDC
- The report referenced airborne spread influenced by RH levels.

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Humidification

ASHRAE 170-2017 Guidelines

Increased awareness of critical affect RH has on virus transmission, Demand by Healthcare Industry

Current allowance for 20% RH min is insufficient, and ineffective against virus spread, and reducing infectivity

- Table 7.1 allows for many spaces well below 40% RH
- Some occupied spaces NR (Not Required)

Table 7.1 Design Parameters—Hospital Spaces

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %
SURGERY AND CRITICAL CARE						
Critical and intensive care	NR	2	6	NR	No	30–60
Delivery room (Caesarean) (m), (o)	Positive	4	20	NR	No	20–60
Emergency department decontamination	Negative	2	12	Yes	No	NR
Emergency department exam/treatment room (p)	NR	2	6	NR	NR	Max 60
Emergency department public waiting area	Negative	2	12	Yes (q)	NR	Max 65
Intermediate care (s)	NR	2	6	NR	NR	Max 60
Laser eye room	Positive	3	15	NR	No	20–60
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes	NR	NR
Newborn intensive care	Positive	2	6	NR	No	30–60
Operating room (m), (o)	Positive	4	20	NR	No	20–60
Operating/surgical cystoscopic rooms (m), (o)	Positive	4	20	NR	No	20–60
Procedure room (o), (d)	Positive	3	15	NR	No	20–60
Radiology waiting rooms	Negative	2	12	Yes (q), (w)	NR	Max 60
Recovery room	NR	2	6	NR	No	20–60
Substerile service area	NR	2	6	NR	No	NR
Trauma room (crisis or shock) (c)	Positive	3	15	NR	No	20–60
Treatment room (p)	NR	2	6	NR	NR	20–60
Triage	Negative	2	12	Yes (q)	NR	Max 60
Wound intensive care (burn unit)	NR	2	6	NR	No	40–60

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Humidification

Advantages:

- Excellent retrofit solution
- Reduced aerosolization of pathogens
- Conducive to more effective immune system behavior.
- Reduces life span of contagion
- Recognized by ASHRAE

Disadvantages:

- Cost of installation and piping
- Maintenance
- RO water

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Questions?

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Ultraviolet Germicidal Irradiation (UVGI)

Ultraviolet Light

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Ultraviolet Germicidal Irradiation (UVGI)

- UV Technology:
  - ASHRAE position documents
  - UV Light Basics
  - Infectious Diseases:
    - Inactivating Airborne Pathogens
  - Applications:
    - Airstream Disinfection/In-Duct “On-the-Fly”
    - Upper-Air/Room Disinfection
    - HVAC Coil/Surface Cleaning

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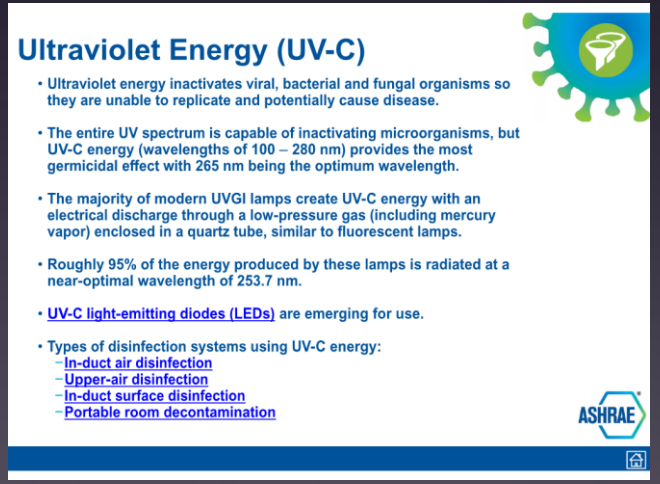
Ultraviolet Germicidal Irradiation (UVGI)

ASHRAE Epidemic Task Force – Filtration & Disinfection

- Air Disinfection:
  - Ultraviolet Energy (UV-C)
    - “Ultraviolet energy inactivates viral, bacterial and fungal organisms so they are unable to replicate and potentially cause disease.”



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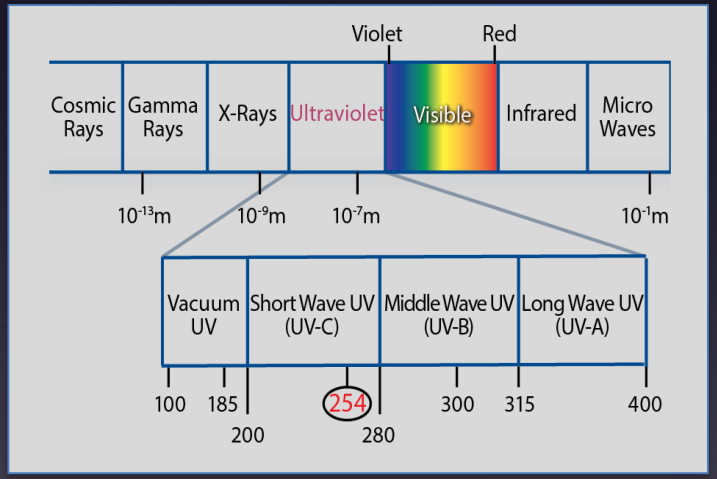
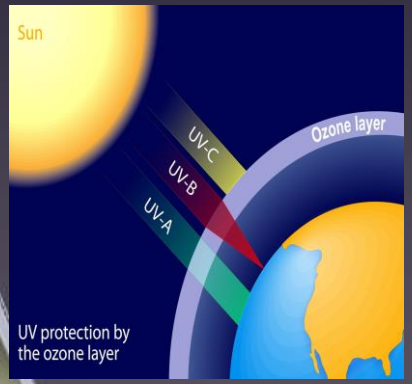
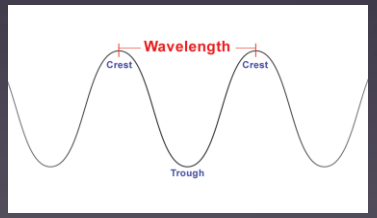
Ultraviolet Germicidal Irradiation (UVGI)

- UV Technology: Basics
  - Electromagnetic Spectrum
  - Energy (heat) transfer via electromagnetic waves.
  - UV Bandwidth: 100 to 400 nm





Greatest source for UV light on earth: The Sun



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Ultraviolet Germicidal Irradiation (UVGI)

Levels of Ultraviolet Light:

UV-A long-wave

Responsible for skin tanning & wrinkles

400-315 nm

UV-B medium-wave;

Primarily responsible for skin reddening and skin cancer

315- 280 nm

UV-C

UV-C short-wave;

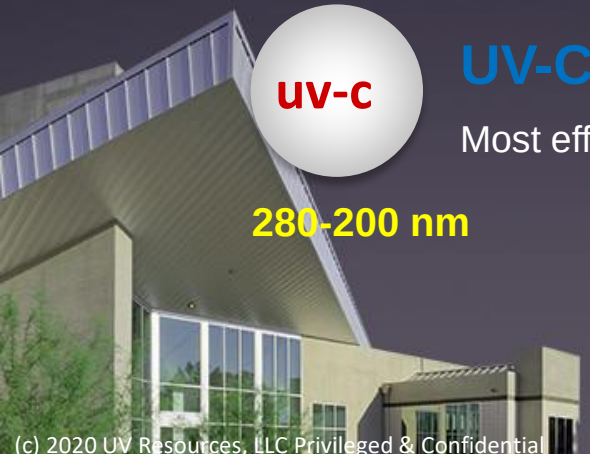
Most effective Germicidal control

280-200 nm

Vacuum UV

Can produce ozone (O3) in air

<200 nm



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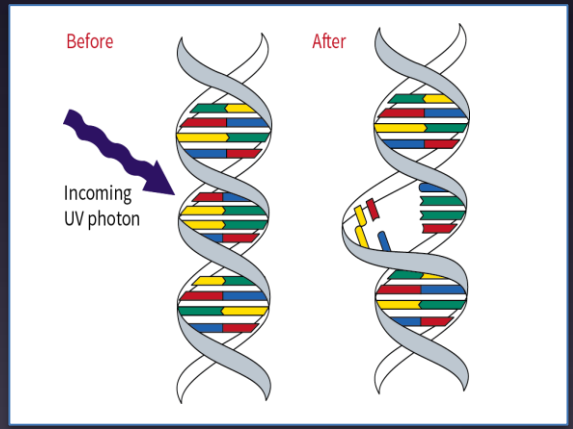
Ultraviolet Germicidal Irradiation (UVGI)

UV-C: 253.7 NM WAVELENGTH

- Inactivates virtually all microbes
  - Breaks molecular bonds of nucleic acids and proteins
  - Deactivates replication of pathogen
- Pathogens absorb UV-C at different rates (called rate constant “K”)



253.7 nm Electromagnetic Energy → Breaks Through Cell Wall → Permanently Damages DNA → Cells Can No Longer Reproduce

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Ultraviolet Germicidal Irradiation (UVGI)

PATHOGEN SUSCEPTIBILITY TO UV-C

Viruses like influenza, measles, SARS, coronavirus and smallpox tend to be more susceptible to UV-C inactivation in an airstream.

Fungal Spores	Bacterial Spores	Mycobacteria	Vegetative Bacteria	Viruses
Aspergillus versicolor	Bacillus anthracis	Mycobacterium tuberculosis	Staphylococcus aureus	Influenza viruses
Penicillium chrysogenum	Bacillus cereus	Mycobacterium bovis	Streptococcus pyogenes	Measles
Stachybotrys chartarum	Bacillus subtilis	Mycobacterium leprae	Escherichia coli	**SARS**
			Pseudomonas aeruginosa	Smallpox
			Serratia marcescens	Corona-virus

LEAST SUSCEPTIBLE — 253.7 nm — MOST SUSCEPTIBLE

SOURCE: ASHRAE Handbook - HVAC Applications Ch.60

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Ultraviolet Germicidal Irradiation (UVGI)

PATHOGEN SUSCEPTIBILITY TO UV-C

At 2,000 *m*W/cm^2 99.9% of coronavirus will be deactivated.

* Microwatts per seconds per cm^2

PATHOGEN	90%	99.9%
MOLD		
• Aspergillus Niger	132,000*	333,000*
BACTERIA		
• Bacillus Subtilis	5,800	11,000
• Mycobacterium Tuberculosis	6,200	10,000
• Staphylococcus Aureus	2,600	6,600
VIRUS		
• Influenza	3,400	6,600
• Coronavirus (Walker 2007)	700	2,000

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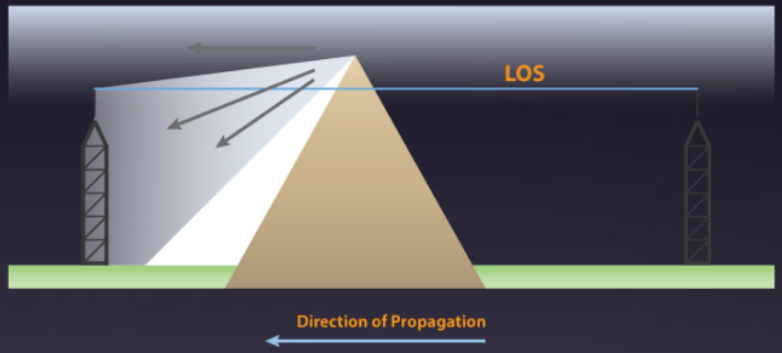
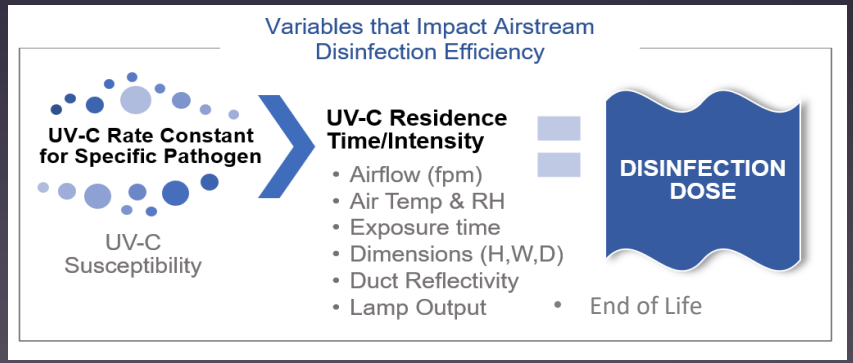
Ultraviolet Germicidal Irradiation (UVGI)

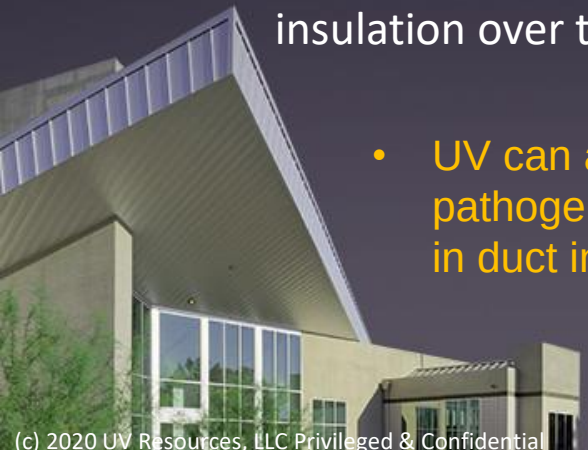
AIRSTREAM DISINFECTION:

- A direct line of sight to surfaces is required for transfer of heat energy.
- Locate UV emitter on discharge side of AHU coil or on the inlet.
  - Upstream, UV can degrade insulation over time.





- UV can also deactivate pathogen **"On-the-Fly"** in duct installations



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Ultraviolet Germicidal Irradiation (UVGI)

Air Disinfection: ASHRAE – Filtration & Disinfection

- UV-C In-Duct Air Disinfection
  - Banks of UV-Lamps installed inside AHU and HVAC or associated ductwork
  - Requires high UV to inactivate microorganisms “on-the-fly”…due to limited exposure time
    - Systems designed for 500 FPM moving airstream
    - Should always be coupled with mechanical filtration

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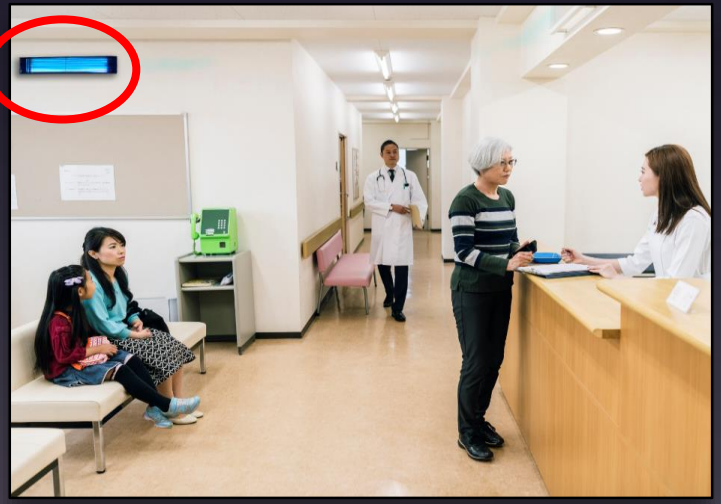
Ultraviolet Germicidal Irradiation (UVGI)

Upper Air/Room Disinfection:

- Wall-mounted >7ft; neutralizes airborne microbes in seconds
- Non-reflective baffles create columnated UV-C beam
- Natural air currents lift contaminated air into UV-C disinfection zone and inactivates pathogen
- Safe for occupied spaces



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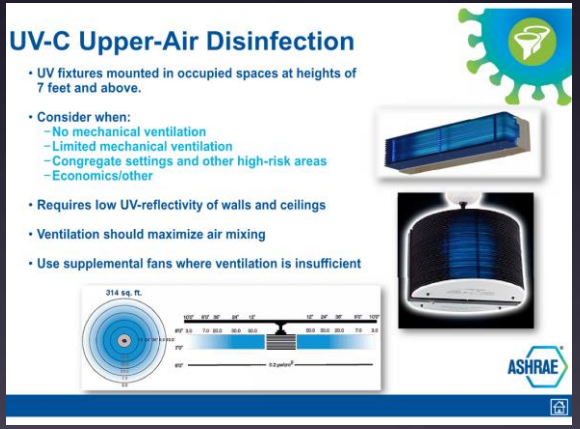
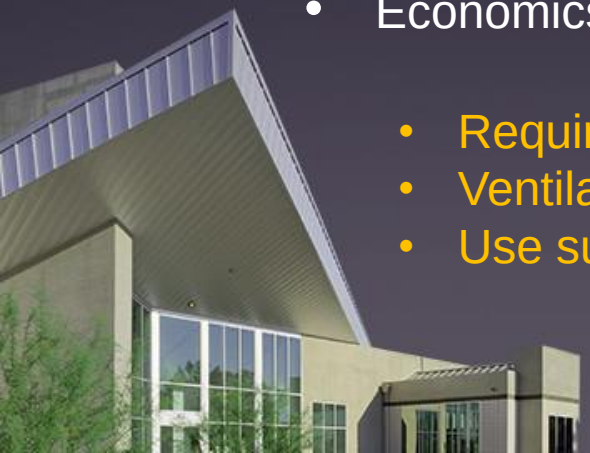
Ultraviolet Germicidal Irradiation (UVGI)

Air Disinfection: ASHRAE – Filtration & Disinfection

- Consider when:
  - No mechanical ventilation or limited mechanical ventilation available
  - High occupant density (ER waiting rooms or conference rooms) and other high-risk areas
  - Economics (first cost)/other factors





- Requires low UV-reflectivity of walls and ceilings
- Ventilation should maximize air mixing
- Use supplemental fans where ventilation is insufficient

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Ultraviolet Germicidal Irradiation (UVGI)

Upper Air/Room Disinfection:

Air Distribution

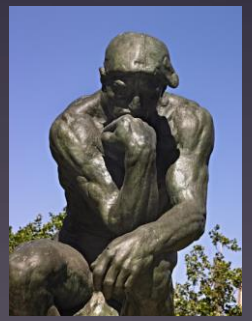
The Mixed Air System Challenge

- To minimize pathogen concentration maximum air mixing must occur for distribution and dilution of contaminant

BUT, WHAT IF?

- Rooftop package units cycle (On/Off)
- VAV boxes reduce air flow to satisfy part load conditions

Will concentrations of contaminate not vary due to reduced mixing at low flow?



UVR UV RESOURCES

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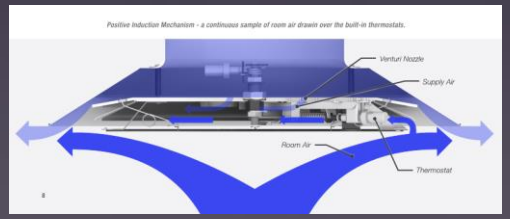
Ultraviolet Germicidal Irradiation (UVGI)

Upper Air/Room Disinfection:

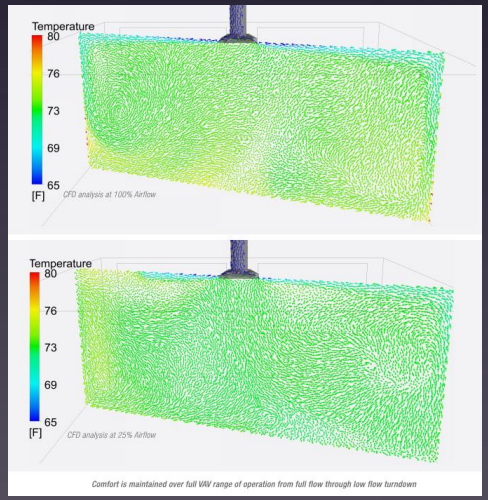
Air Distribution

To optimize mixing consider using low pressure VAV diffusers

- VAV diffusers maintain discharge velocity even at 25% of design flow
- Room air is continuously induced into the supply jet even at 25% of flow



The Mixed Air System Challenge



100% Flow

25% Flow

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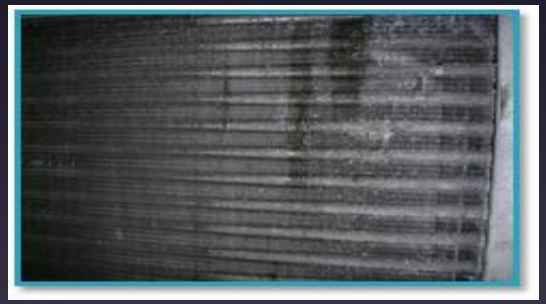
Ultraviolet Germicidal Irradiation (UVGI)

WEEK 1



WEEK 5

Coil Surface Cleaning:

- Restoration and preservation of heat transfer efficiency and airflow capacity (1990s)
- Reduce coil fouling and system maintenance
- Slash HVAC energy consumption by up to 25%
- Improves indoor air quality (IAQ) and reduces airborne pathogens

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Ultraviolet Germicidal Irradiation (UVGI)

ASHRAE – Filtration & Disinfection

AHU Coil Surface Cleaning

- Banks of UV-Lamps installed inside HVAC systems, generally focused on:
  - Cooling coils
  - Drain pans
  - Other wetted surfaces
- **(AHU) UV irradiance** can be lower than in-duct air disinfection systems due to long exposure times
- Goals are:
  - Even distribution of UV energy across the coil face
  - Generally, 12 to 36 inches from the coil face
  - Operated 24 hours a day, 7 days a week

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Ultraviolet Germicidal Irradiation (UVGI)

Advantages:

- Excellent retrofit solution
- Reduced pathogen deactivation time
- No increase in system static pressure
- Recognized by ASHRAE
- Utility Rebates: Currently Under Review

Disadvantages:

- Requires direct line of sight for effectiveness
- UV lamps to be replaced once a year
- Occupant UV exposure a consideration
- Not tested for SARS-CoV-2

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Questions?

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Ionization

Indoor Air Quality (IAQ)

Is the only solution for pollution dilution?

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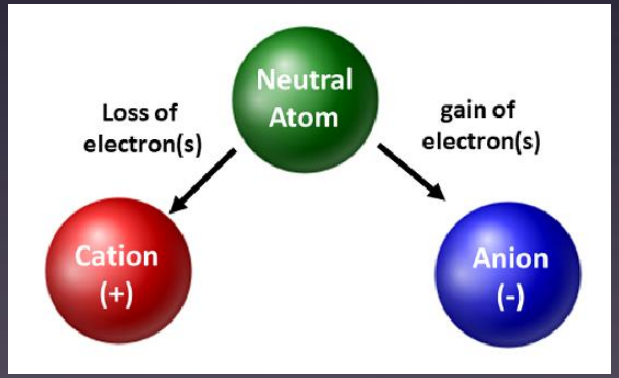
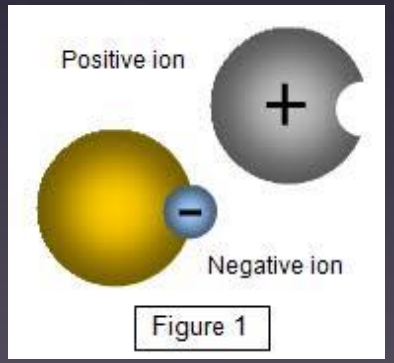
Ionization

What are Ions?

- An ion is an atom or molecule with a net electric charge due to the loss or gain of one or more electrons





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Ionization

Molecular Cloud:
Ionized Hydrogen & Oxygen

M42 (The Orion Nebula)

Photo taken with a Canon T3 at 200mm FL

(15) Image frames and (40) Calibration Frames

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Ionization

IONS ARE NATURALLY OCCURRING

Ions are present naturally in the air and are found in the highest concentrations where the ocean meets the shore and high elevation in the mountains.

The GPS plasma process will artificially create ions found in these locations and supply them into the building, enhancing the indoor air quality.

Units of Measure = Ions/cc/sec

- Waterfalls/Elevation = 5,000
- City = 200
- Inside Buildings <100

← Naturally occurring ion densities

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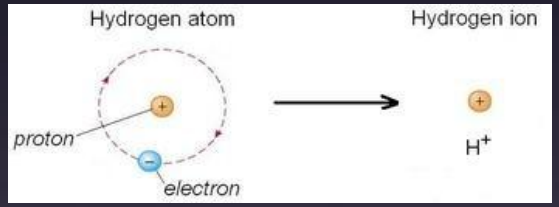
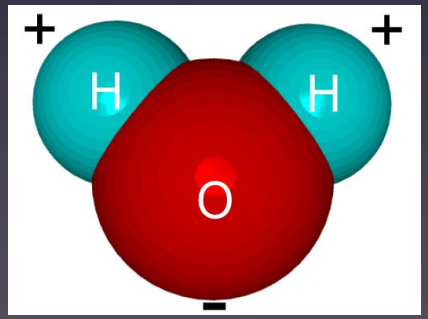
Ionization

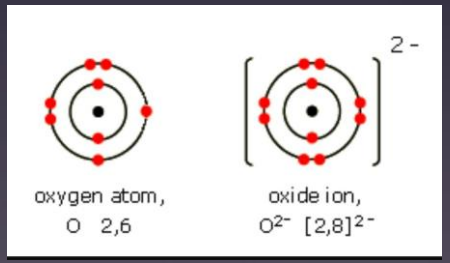
Hydrogen/Oxygen Ions



Hydrogen ion, strictly, the nucleus of a **hydrogen** atom separated from its accompanying electron. The **hydrogen** nucleus is made up of a particle carrying a unit positive electric charge, called a proton.

H20 molecule (Vapor)





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Ionization

Needlepoint Bi-polar Ionization

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Ionization

Steady-State Ionization

An ion is an atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons.

- When high voltage of both polarities is continuously applied to a pair of positive (+) and negative (-) emitter points.
- Oppositely charged Hydrogen and Oxygen Ions are produced from water vapor in the air creating **plasma**
- **This process is known as Bi-Polar Ionization**.

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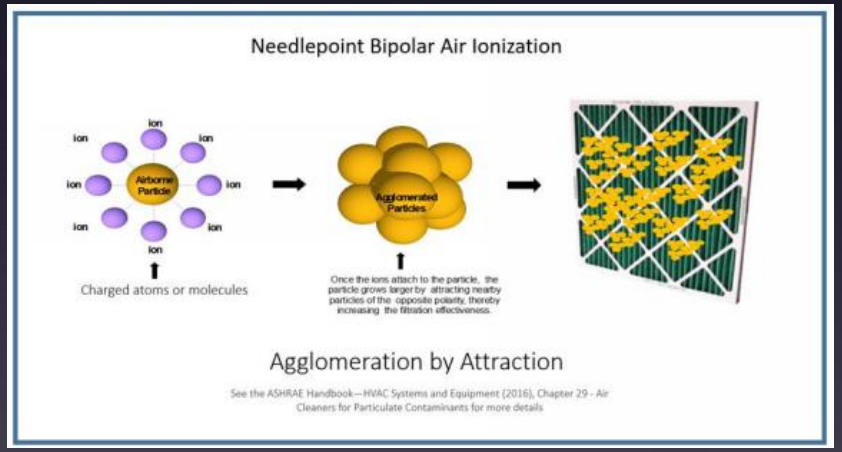
Ionization

Agglomeration

Ions adhere to larger particles in the space giving them a positive or negative electrical charge.

Particles electrostatically bond and become larger and more massive



MERV-8 filtration can approach the efficiency of MERV-13 filters.

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Ionization

ma Effectiveness
VOC Chemical Compounds

Ion plasma breaks down molecular structures with electron bonding potentials of 12.0 electron volts or less

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**
Methane	**CH_4**	**12.61**

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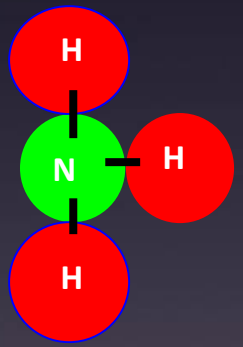
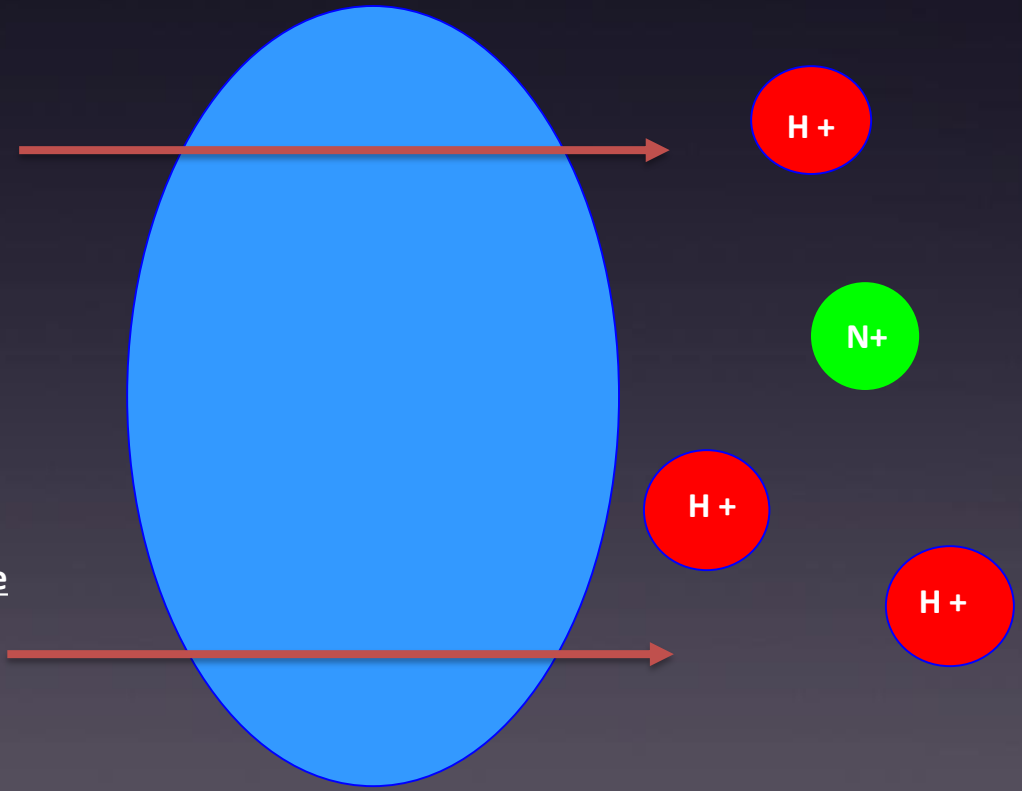
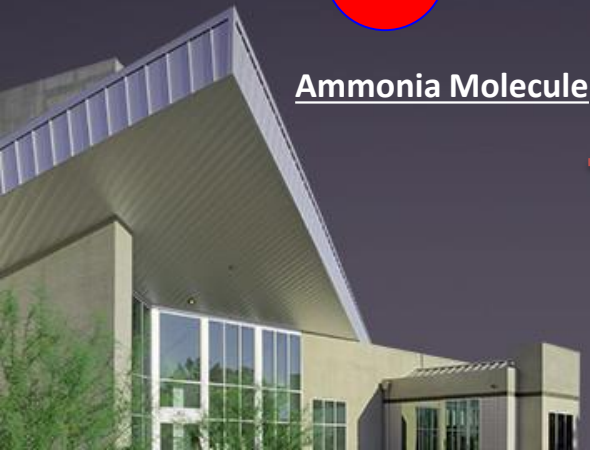
Ionization

Plasma Field



Ammonia Molecule





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Ionization

Oxygen

Nitrogen

Water Vapor

Objectionable Gases Regroup To Form Safe & Desirable Gases Already Prevalent in Our Atmosphere!

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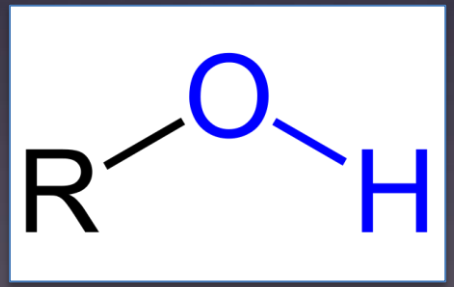
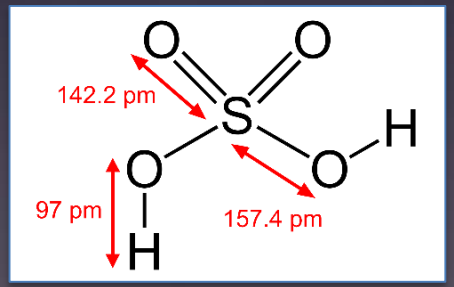
Ionization

Deactivates Mold, Viruses and Bacteria

IN THE SPACE

- Positive and negative ions react to form **Hydroxyls** (Nature's Friendly Detergent)





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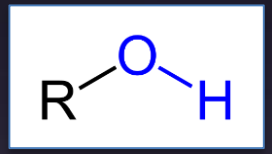
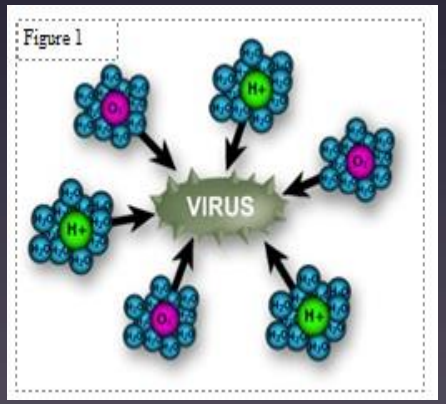
Ionization

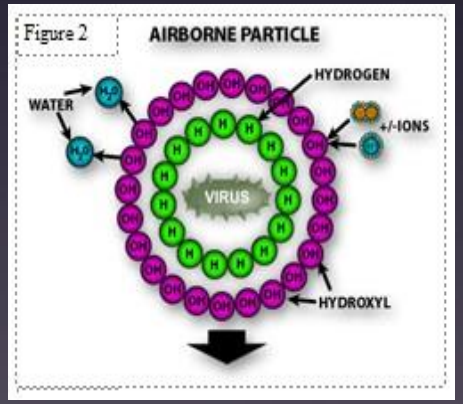
- **Hydroxyl Radicals**, due to their negative charge, surround the infectious particle





Hydroxyl Radical
(Valence Charge – 1)

Hydroxyl Radicals rob hydrogen from nucleic acids; RNA/DNA molecules



Germicides cannot reproduce)

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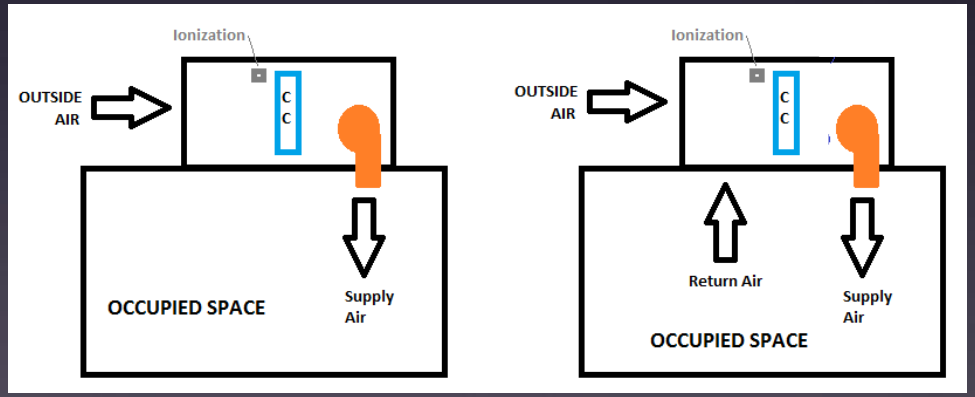
Ionization

Independent Testing by World Renowned EMSL & ATS Labs

Pathogen	Time Exposed	Kill Rate
E.coli	15 minutes	99.68%
MRSA	30 minutes	96.24%
TB	60 minutes	69.01%
Noro Virus	30 minutes	93.50%
Feline Calicivirus	30 minutes	93.50%



THE ONLY TECHNOLOGY PROVEN TO KILL PATHOGENS IN THE SPACE

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Ionization

ABSTRACT

April 2020 Laboratory Testing of Human Coronavirus 229E
GPS Needlepoint Bipolar Ionization (NPBI)

Global Plasma Solutions (GPS) Disclaimer:
GPS does not make performance validation claims using a single data point resource. GPS technology is used in a wide range of applications across diverse environmental conditions. It is the responsibility of the client to evaluate their application and environmental conditions in making an assessment regarding the technology's potential benefits in their use.

ALG
ATLANTIC LAB GROUP

Test Parameters:

Organic Soil Load:	1% fetal bovine serum
Test Medium:	Minimum Essential Medium (MEM) supplemented with 2% (v/v) heat-inactivated, 100 units/mL penicillin, 10 µg/mL gentamicin, and 2.5 µg/mL amphotericin B
Indicator Cell Cultures:	WI-38 (human lung) cells

Exposure Temperature:	Room temperature (22.0°C)
Exposure Humidity:	22.83% for the tests and cytotoxicity control 23.38% for the dried virus controls

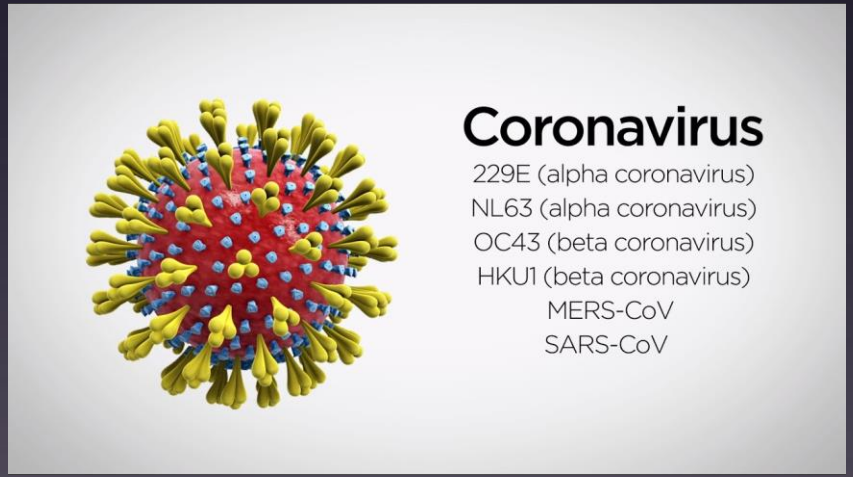
Chamber Ion Concentrations x 1000:

Cytotoxicity control:	-0.36
1 Minute Exposure:	0.34
5 Minute Exposure:	0.46
15 Minute Exposure:	1.07
30 Minute Exposure:	0.86
60 Minute Exposure:	1.48

Test Result: 90% Reduction versus control after 60-minute exposure.

60 Minute Exposure
A 1.00 $\log_{10}$ reduction in viral titer was demonstrated, per volume inoculated per well and per carrier, compared to the titer of the 60 minute dried virus control.

In the opinion of the Author, there were no circumstances that may have affected the quality or integrity of the data.



Corona Virus 229E

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Ionization

SARS-CoV-2: Aviation Industry Testing Results

Global Plasma Solutions Ion Effectiveness:

- Innovative BioAnalysis Test Lab tested ion plasma effectiveness for inactivating SARS-CoV-2, known as COVID-19
  - SARS-CoV-2 sample residing on medium in petri dish
  - Based on an ion density of approximately **27,000 ions/cc** to simulate densities found in the upper atmosphere:
    - **10-minutes: 84.2% inactivated**
    - **15-minutes: 92.6% inactivated**
    - **30-minutes: 99.4% inactivated**

INNOVATIVE BIOANALYSIS
creating solutions | getting results

Innovative Bioanalysis
5630 Cerritos Ave
Cypress CA, 90630
www.InnovativeBioanalysis.com
Email: Albert.Brockman@innovativebioanalysis.com

SARS - CoV - 2 Neutralization by Needlepoint Bipolar Ionization, Powered by GPS

CLIENT: ACA/IAE

PROJECT: Needlepoint Bipolar Ionization "NPBI™" applied to COVID19

PRODUCT: ACA-RN-0001 and ACA4800GU-1, Powered by GPS DM48 - AC NPBI™ Technology
CAP LIC NO: 9501843
CLIA LIC NO: 05D1064850

SAMPLE RECEIVED: 05/21/2020
START DATE: 05/27/2020
REPORT DATE: 06/02/2020
CHALLENGE VIRUS: SARS-CoV-2

EXPERIMENTAL SUMMARY:

Single RE22 control chambers set on a table stainless steel table with pressure verification seals. Internal working dimensions 16.5"W x 9"H x 12"D for a total cubic footage of 1.031. Under initial observation it was determined to seal the unit completely with no intake or exhaust port. Control ionization counts were performed prior to initial test. Testing and control were conducted in an average ambient temperature of 72.6 degrees Fahrenheit.

A singular fan unit was set up at a 45-degree angle to the two ionization units affixed to the testing chamber. The initial control fan speed was measured at an average of 870 Ft/m. At these airflow speeds the initial ionization saturation counts were taken so adjustment could be made to lower or raise ionization levels depending on the testing parameters needed. Under the original control section, the primary fan was set 10 inches away from ion production unit A and the average air flow speed past the ion producing nodes was 250Ft/m

1
Innovative Bioanalysis

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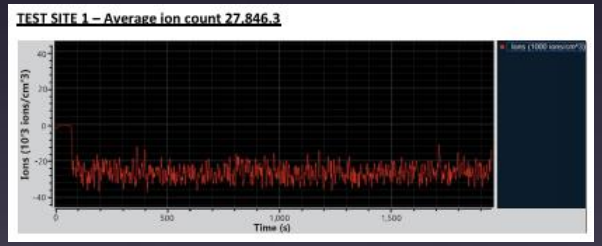
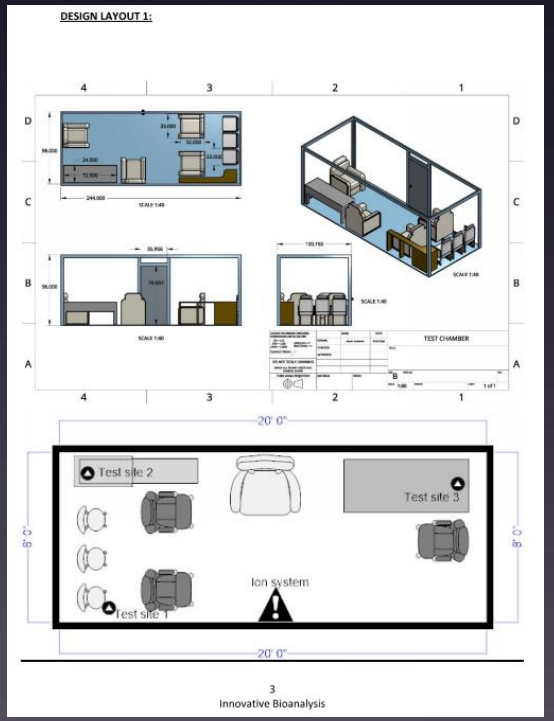
Ionization

SARS-CoV-2: Aerosolized Testing Results

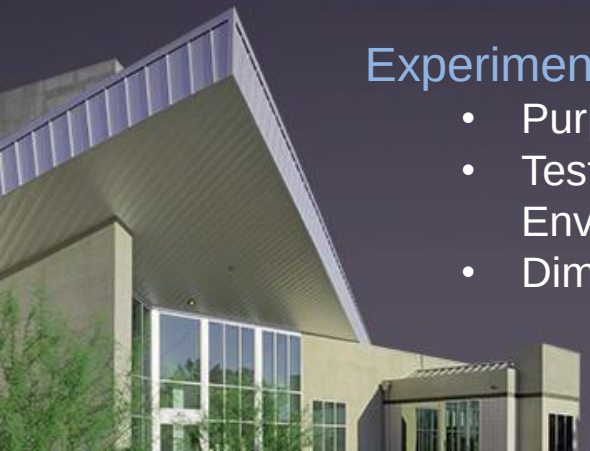
Ion densities of 26,000 ions/cc & above for aircraft at altitude





Experimental Summary:

- Purpose: Direct Aerosol Testing
- Test Chamber: Simulate Working Environment with Air Flow Obstacles
- Dimensions: 20ft x 8ft x 8ft deep



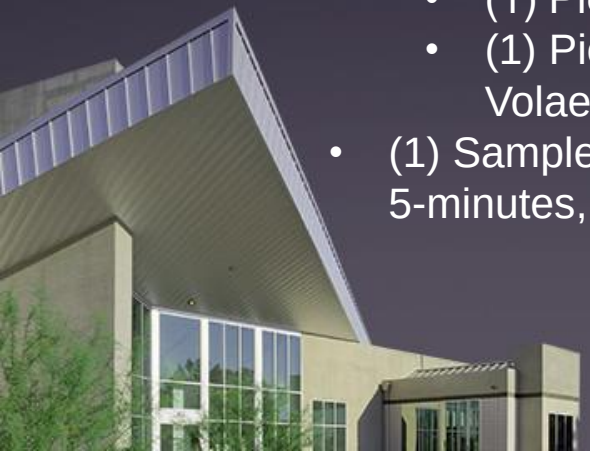
Ionization

SARS-CoV-2: Aerosolized Testing Results

Test pieces inoculated with aerosolized virus solution from 6 inches away

Experimental Summary:

- Three Room Test Sites: #1, 2 & 3
  - Ion Counters at Each Site
  - (1) Piece of Kydex-6565 @ 0.125” thick
  - (1) Piece of Aluminum @ 0.030” thick
  - (1) Piece of Leather: Aristo (P/N King Volaero 1388Q)
- (1) Sample swab taken from each test piece at 5-minutes, 15-minutes and 30-minutes



TESTING PROCEDURE:

VIRAL STOCK: SARS-CoV-2 USA_WA1/2020 (BEI NR-52281)

TEST	SPECIFICATIONS	RESULTS
Identification by Infectivity in Vero 6 cells	Cell Rounding and Detachment	Cell Rounding and Detachment
Sequencing of Species-Specific Region (Approx. 940 Nucleotides) (Approx. 940 Nucleotides	≥ 98% identity with SARS-CoV 2, isolate USA-WA1/2020 GenBank: MN985325.1 ≥ 98% identity with SARS-CoV 2, strain FDAARGOS_983 isolate USA-WA1/2020 GenBank: MT246667.1	100% identity with SARS-CoV 2, isolate USA-WA1/2020 GenBank: MN985325.1 100% identity with SARS-CoV 2, strain FDAARGOS_983 isolate USA-WA1/2020 GenBank: MT246667.1
Genome Copy Number using Biorad QX200 Droplet Digital PCR.	Report Results	2.07 X 10^9 genome equivalents per mL
Titer by TCID50 in Vero 6 Cells by Cytopathic effect	Report Results	2.8 X 10^5 TCID50 per mL in 6 days at 37°C and 5% CO2
Sterility (21-Day Incubation) Harpos HTYE Broth, aerobic Trypticase Soy Broth, aerobic Sabourad Broth, aerobic Sheep Blood Agar, aerobic Sheep Blood Agar, anaerobic Thioglycollate Broth, anaerobic DMEM with 10% FBS	 No Growth No Growth No Growth No Growth No Growth No Growth No Growth	 No Growth No Growth No Growth No Growth No Growth No Growth No Growth
Mycoplasma Contamination Agar and Broth Culture DNA Detection by PCR of extracted Test Article nucleic acid.	 None Detected None Detected	 None Detected None Detected

TCID50 PROCEDURE:

MATERIALS AND EQUIPMENT:

- Certified Biological Safety Cabinet
- Micropipette and sterile disposable aerosol resistant tips – 20uL, 200 uL, 1000uL
- Inverted Microscope

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Ionization

SARS-CoV-2: Aerosolized Testing Results

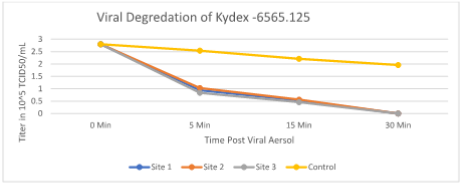
Conclusions:

- Aluminum-2024 TE.030:
  - "…After 30-minutes, the overall average decrease in active virus was 99.89%.
- Kydex-6565.125:
  - "…After 30 minutes, the overall average decrease in active virus was 99.99%.
- Leather:
  - "… After 30 minutes, the overall average decrease in active virus was 99.99%.

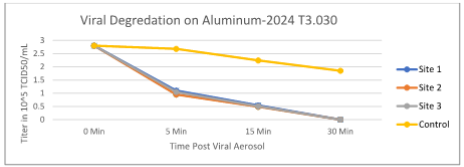
"…it is safe to say that bipolar ionization system used in this experiment has the ability to deactivate SARS-CoV-2 with the given ion counts

EFFICACY TESTING:

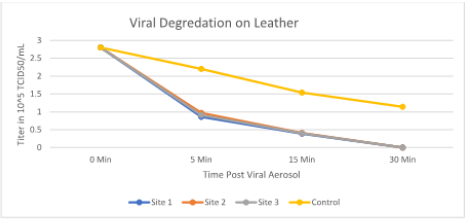
Viral media with a known concentration was applied via aerosol to the materials in 3 locations throughout the containment unit and exposed to bipolar ionization for a period of 5, 15, and 30 minutes. Swabs were taken of all material and cultured by the same means as the original viral titration performed on the BEI Resources provided SARS-CoV-2 USA-WA1/2020 viral culture. Preliminary results are as follows



Kydex Log10 Reduction from 0 min to 30min Site 1: 3.75, Site 2: 3.7, Site 3: 3.71 Control: 0.15



Aluminum Log10 Reduction from 0Min to 30 min: Site 1: 3.73, Site 2: 3.65 Site 3: 3.61 Control: 0.18



Leather Log10 Reduction from 0 min to 30 min: Site 1: 3.72, Site 2: 3.75, Site 3: 3.75 Control: 0.39

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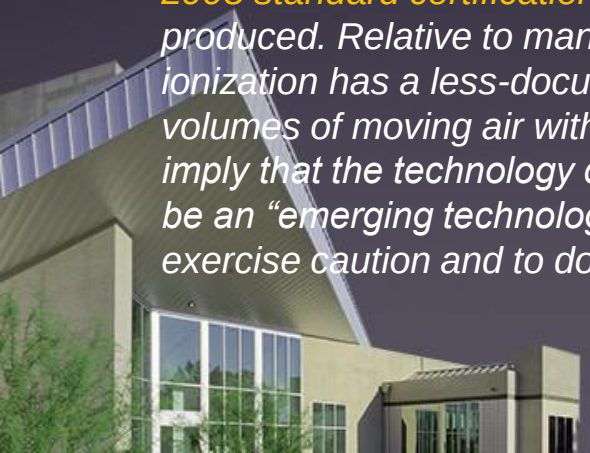
Ionization

ASHRAE Epidemic Task Force

CDC Position on Bipolar Ionization

ASHRAE does not currently have a Society position on bipolar ionization. However, the ASHRAE ETF did reach out to CDC for their position on the technology. The following is the response from CDC in its entirely:

"…While bi-polar ionization has been around for decades, the technology has matured and many of the earlier potential safety concerns are reportedly now resolved. If you are considering the acquisition of bi-polar ionization equipment, you will want to be sure that the equipment meets UL 2998 standard certification… which is intended to validate that no harmful levels of ozone are produced. Relative to many other air cleaning or disinfection technologies, needlepoint bi-polar ionization has a less-documented track record in regards to cleaning/disinfecting large and fast volumes of moving air within heating, ventilation, and air conditioning (HVAC) systems. This is not to imply that the technology doesn't work as advertised… the technology is still considered by many to be an "emerging technology". As with all emerging technologies, consumers are encouraged to exercise caution and to do their



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Ionization

Global Plasma Solutions

UL 867 vs UL 2998

- UL 867 – All EACs tested to this standard for electric safety
  - Requires an ozone test, if the EAC is a portable room air cleaner
  - If product is duct mounted, no ozone test required! LOOP HOLE!
  - Ozone limit is 50.0 PPB when testing required
- UL 2998 – Certification Standard "Certifies Ozone Free Technology"
  - Uses same ozone chamber test as UL 867
  - Maximum ozone output is 5.0 PPB!
  - Now required per ASHRAE 62.1-2019 Section 5.7.1
  - Applies to all devices requiring power to purify the air
  - Includes UV Lights, Polarized Filters, Ionizers, etc.

UL compliance for ozone generation

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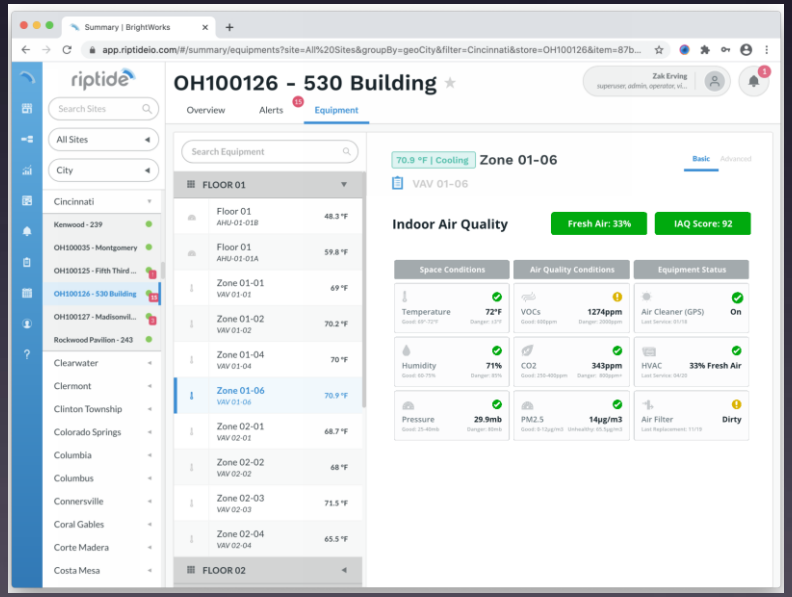
Ionization

Riptide: Cloud Based Controls

- Dynamic Display of IAQ calculation
- VOC Concentration Display



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Ionization

Ionization Advantages:

- Excellent cost effective retrofit solution
- No increase in system static pressure
- Maintains effectiveness in the occupied space and beyond
- Effectively tested for SARS-CoV-2 (COVID-19)
- Scalable solution (VRV Application)

Disadvantages:

- ASHRAE has not formally acknowledged the technology

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Questions?

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ASHRAE: Dilution

Session Three:
Minimizing & Neutralizing Pathogen Transfer

Wednesday November 4th, 2020
Time: (12:00 Noon)

- Airflow Patterns
- Indoor Air Quality
- System Integration

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Thank you.

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Filtration

ASHRAE: Epidemic Task Force

- ASHRAE Standard 52.2-2017 Minimum Efficiency Reporting Value
  - Identifies “Dust Holding Capacity”, i.e. “the total weight of synthetic loading dust captured by the air cleaning device over all of the incremental dust loading steps.”
  - Expresses efficiency as a function of specific particle size (PSE).

TABLE 2: ANSI/ASHRAE 52.2 PARTICLE SIZE RANGES

Range	Size	Group
1	0.30 to 0.40	E1
2	0.40 to 0.55	
3	0.55 to 0.70	
4	0.70 to 1.00	
5	1.00 to 1.30	E2
6	1.30 to 1.60	
7	1.60 to 2.20	
8	2.20 to 3.00	
9	3.00 to 4.00	E3
10	4.00 to 5.50	
11	5.50 to 7.00	
12	7.00 to 10.00	

Group E1: Size: 0.30 to 1.00
Group E2: Size :1.00 to 3.00
Group E3: Size: 3.00 to 10.00

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Filtration

ASHRAE: Epidemic Task Force

- ASHRAE Standard 52.2-2017 Minimum Efficiency Reporting Value (MERV)

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0	Average Arrestance, %
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg}$
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg}$
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

ASHRAE Standard 52.2-2017 Minimum Efficiency Reporting Value (MERV)

MERV8: (microns/%)
- 0.30 to 1.0: N/A
- 1.0 to 3.0: 20% or less
- 3.0 to 10.0: 70% or less

MERV13: (microns/%)
- **0.30 to 1.0: 50% or less**
- 1.0 to 3.0: 85% or less
- 3.0 to 10.0: 90% or less

MERV14: (microns/%)
- 0.30 to 1.0: 75% or less
- 1.0 to 3.0: 90% or less
- 3.0 to 10.0: 95% or less

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Filtration

ASHRAE: Epidemic Task Force

- Mechanical Air Filters:
  - (MINIMUM EFFICIENCY REPORTING VALUE (MERV): The fraction of particles removed from air passing through a filter is termed “filter efficiency”.

- MERV Ratings:
  - MERV ranges from 1 to 16: Higher MERV = higher efficiency
  - MERV 13 or greater: Efficient @ capturing airborne viruses
  - MERV 14: Preferred
  - High Efficiency particulate air (HEPA) filters

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