Health & Well-Being: One Breath at a Time

Presented by: Dan Hahne
Varitec: Director of High-Performance HVAC Solutions

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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 Sales
    - 2000 thru 2008
  - Air Specialty Products / ThermAir Systems – Engineering Sales
    - 2009 thru 2016
  - **Varitec Solutions:**
    - Director of High-Performance HVAC Solutions/Educator
    - 2016 thru present

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Introduction

Publications:

- **July 2022: 100% Outside Air VRF Systems: A Sustainable, Hybrid Approach for Superior IEQ**
  - Dan Hahne
- **October 2021: Health Care Design: Beyond Code Minimum – Creating Healthier, More Efficient Environments**
  - (Co-Authored with Fletcher Clarcq P.E.)
- **June 2021: Health Care Design: ANSI/ASHRAE/ASHE Standard 170, and Beyond**
  - (Co-Authored with Fletcher Clarcq P.E.)
- **November 2019: Debunking the Myths of Active Chilled Beams: What You Thought You Knew But Were Wrong**
  - (Co-Authored with Eric Martin P.E., Fletcher Clarcq P.E. Steven Lamica, Engineer (Dadanco))
- **October 2019: Debunking the Myths of Active Chilled Beams: The Drip Test**
  - (Co-Authored with Eric Martin P.E., Fletcher Clarcq P.E. Steven Lamica, Engineer (Dadanco))

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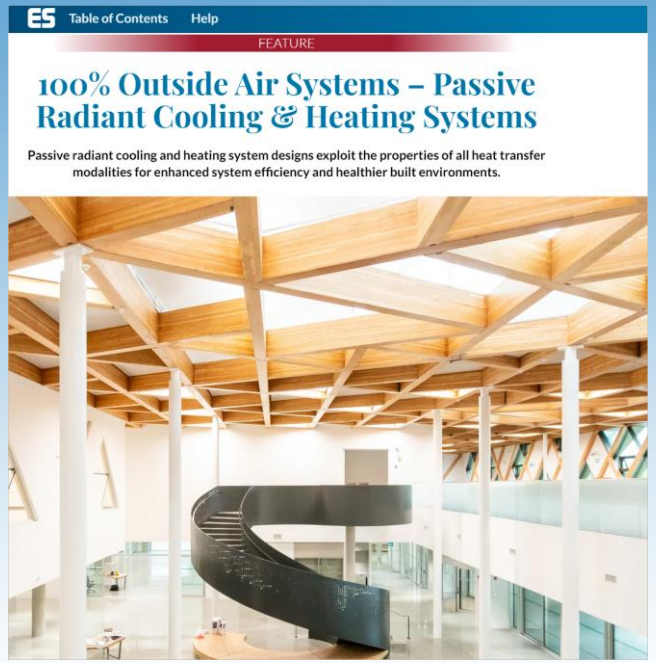
Latest Publication

Engineered Systems Magazine: December 2022 Edition

- *100% Outside Air Systems – Passive Radiant Cooling and Heating Systems*



- **(Co-Author: Darren Alexander, P.E. (Twa Panel Systems, Inc.)**

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Varitec: The HVAC System Solution

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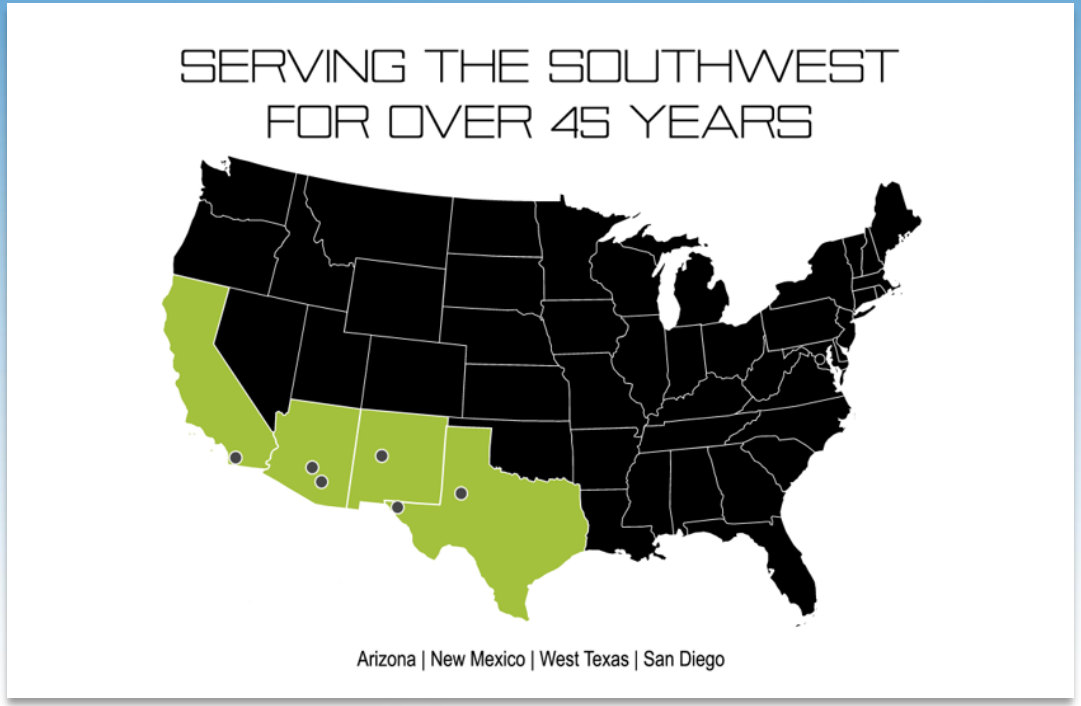

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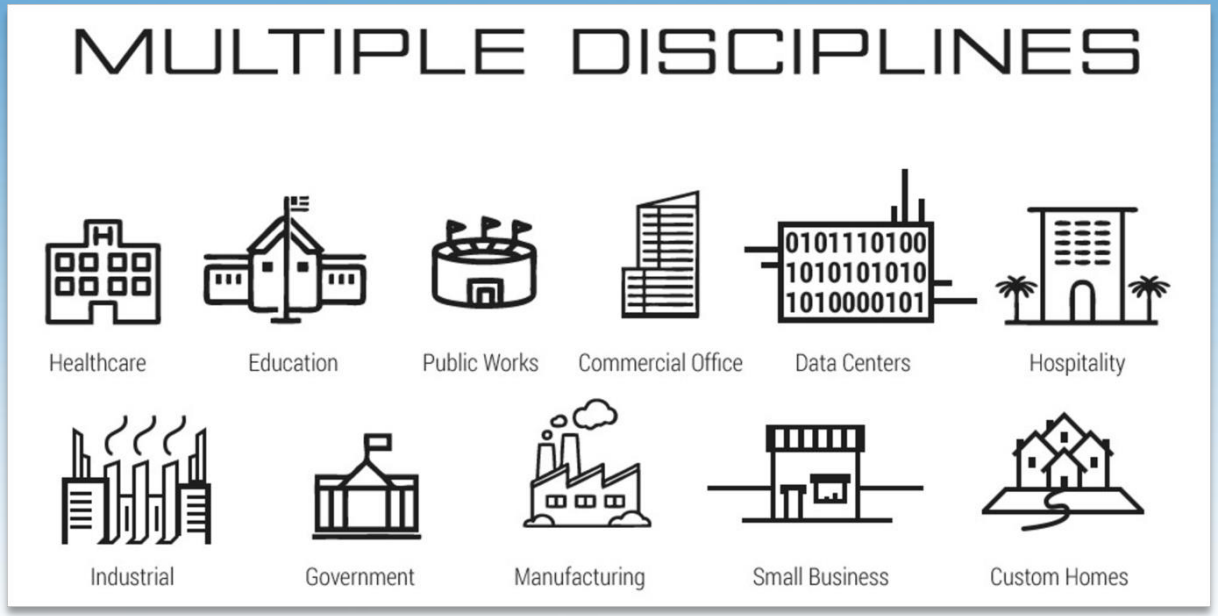

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- Mixed Air VAV Systems
- Package Central Plants for Air & Water Cooled Designs
- Cloud Based Controls
- Humidity Control
- Underfloor Air Systems
- 100% OSA Systems
  - DOAS Technology
  - Active Chilled Beams
  - Passive Hydronic Cooling & Heating Systems

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Mission:

To provide an educational platform for continued learning in the HVAC industry with a focus on high performance buildings and innovative technologies for a better built environment.

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February 15th : Health & Well-Being, One Breath at a Time

March 22nd : Fundamentals of HVAC

- Session #1: Fundamentals of HVAC Systems

April 19th: Fundamentals of HVAC

- Session #2: Toward Healthier Buildings, Humidifica

May 10th: Fundamentals of HVAC

- Session #3: Psychrometrics Deconstructed Part 1

June 14th : Fundamentals of HVAC

- Session #4: Psychrometrics Deconstructed Part 2

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July 12th: Fundamentals of HVAC

- Session #4: The Physics of Air Flow

September 13th: 100% Outside Air Systems

- The Importance of Venitiation & Building Design Considerations

October 11th: Thermally Stratified Environments

November 8th: Underfloor Air Systems

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VARITEC™ IEQ, Net Zero & HVAC | February 2023

TODAY'S DEVELOPMENTS FOR TOMORROW'S WORLD

What you need to read this month

Developing global and national initiatives will impact how buildings are designed in the future. In 2021, the Department of Energy (DOE) issued a determination ASHRAE Standard 90.1-2019 will be adopted into State commercial building codes to meet or exceed the standard. In 2022, ASHRAE initiated its Task Force for Building Decarbonization to reduce operational carbon emissions by increasing building efficiency. On another front, the pandemic demonstrated the need to reduce a building's risk of infection resulting in federal initiatives to supply better indoor air quality (IAQ). In October of 2022, the White House instituted its "Clean Air in Buildings Challenge" to provide a range of resources and recommendations for improving IAQ followed in December by ASHRAE's expressed commitment to writing an IAQ Pathogen Mitigation Standard. Consequently, what appear to be conflicting pressures, creating better IAQ and improving building energy efficiency, have posed a dilemma to design groups and building owners.

In response to this ever-changing market dynamic, Varitec's Technical Institute will be writing a monthly newsletter to inform building owners and industry professionals on:

- ASHRAE developments toward electrification, decarbonization, and enhanced IAQ.
- Federal initiatives and directives for net-zero carbon and increased operational efficiency
- Government initiatives to create healthier environments through superior IAQ.
- Technological developments that impact the built environment
- Design concepts and promising technology that will span the divide between superior IAQ and greater energy efficiency.

Varitec; supporting our community for a better tomorrow.

Want to submit an article for next month? Click Here

Introducing the Inflation Reduction Act Guidebook

BUILDING A CLEAN ENERGY ECONOMY:

A GUIDEBOOK TO THE INFLATION REDUCTION ACT'S INVESTMENTS IN CLEAN ENERGY AND CLIMATE ACTION

This guidebook provides an overview of the clean energy, climate mitigation and resilience, agriculture, and conservation-related tax incentives and investment programs in the Inflation Reduction Act, including who is eligible to apply for funding and for what activities. The Administration is working quickly to design, develop, and implement these programs; as such, the information in this guidebook is current as of publication. In the coming weeks and months, we will publish new developments on www.CleanEnergy.gov to keep stakeholders and potential beneficiaries of these programs up to date on the latest deadlines and details. This guidebook does not cover the Inflation Reduction Act's health care provisions or certain corporate tax reforms.

Read More

Varitec's Newsletter:

Today's Developments for Tomorrow's World

- Recent actions and programs from the Federal Government
- Developments in the Green Building movement
- AIA's 2030 Commitment
- HVAC solutions for healthier more efficient buildings

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Health & Well-Being: One Breath at a Time

AGENDA

- ASRAE Epidemic Task Force: Indoor Air Quality (IAQ) Guidelines
- EPA and CDC & White House Statements on IAQ
- Air Quality, Contaminants & CO_2
- The Indoor Environment
  - The Importance of Ventilation & IAQ
  - ASHRAE: Review of “Ventilation-Related” Strategies
- Department of Energy, ASHRAE Standard 90.1-2019 & IAQ:
  - Spanning the Divide

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ASRAE Epidemic Task Force: Indoor Air Quality (IAQ) Guidelines

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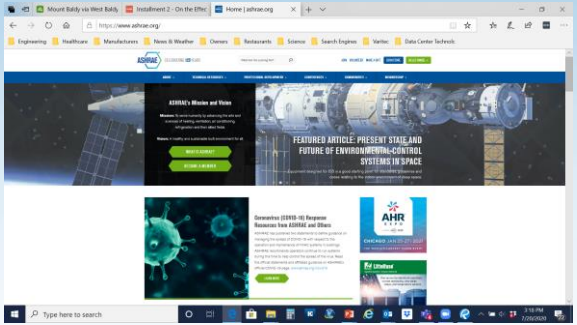
ASRAE Epidemic Task Force: Indoor Air Quality (IAQ) Guidelines

American Society of Heating, Refrigeration and Air Conditioning Engineers: ASHRAE

ASHRAE Position Document on Infectious Aerosols:

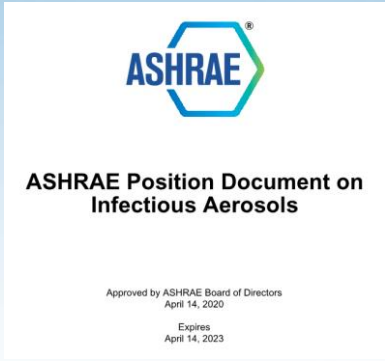
ASHRAE Epidemic Task Force



(Website Release: March 30, 2020)

(www.ashrae.org)

- **Provide Building Guides for:**
  - Schools & Universities
  - Healthcare
  - Dental Guidance
  - Commercial
  - Laboratory
  - Communities of Faith…
  - Residential
  - Multifamily



(Published: April 14th, 2020)

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ASRAE Epidemic Task Force: Indoor Air Quality (IAQ) Guidelines

ASHRAE: *Statement Regarding the Transmission of SARS-CoV-2*

ASHRAE.ORG/COVID19

(ASHRAE Statements)

- "**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."**

- **ASHRAE Standard 62.1-2019:**
  - **Ventilation:** "the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space."
  - **Note: Per ASHRAE, it is not necessarily outside air.**

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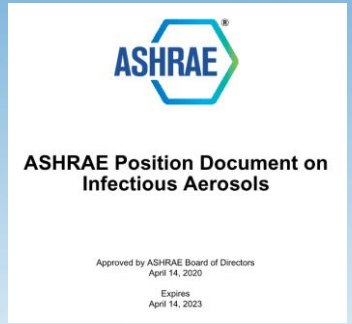
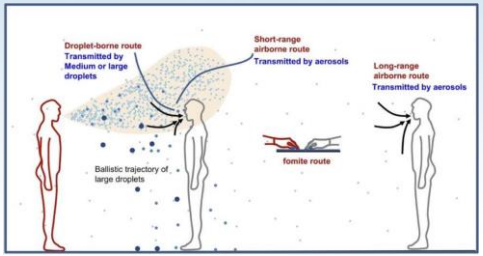
ASRAE Epidemic Task Force: Indoor Air Quality (IAQ) Guidelines

ASHRAE: Position Document on Infectious Aerosols

- **Abstract:**
  - "Some diseases are known to spread by infectious aerosols."
  - The risk of pathogen spread … can be affected both positively and negatively by the **airflow patterns in the space and by heating and ventilating, and air-conditioning (HVAC)...**"
  - "Chief among these **ventilation-related strategies** are
    - **Dilution**
    - **Airflow Patterns**
    - Pressurization
    - Temperature
    - **Humidity Distribution & Control**
    - Filtration
    - **Ultraviolet Light Germicidal Irradiation (UVGI)**





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EPA and CDC & White House: Statements on IAQ

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EPA and CDC & White House: IAQ Statements

SARS-CoV-2 Transmission: The Challenge

TIME

ARTICLE: Published August 25th, 2020

By: Jose-Luis Jimenez, Ph.D

(Professor of Chemistry and a Fellow of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado-Boulder)

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

"Contrary to public health messaging, I, together with many other scientists, believe that **a substantial share of COVID-19 cases are the result of transmission through aerosols**."

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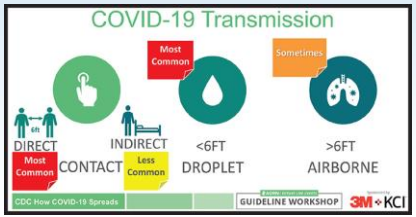
EPA and CDC & White House: IAQ Statements

SARS-CoV-2 Transmission: The Challenge

TIME

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

"Fomites and droplets have dominated our everyday understanding of COVID-19 transmission. While the **WHO and CDC** both state that aerosols ***could*** lead to transmission under highly specific situations, **both organizations maintain that they are less important.**



"**I believe this is a significant mistake** and on July 6th I, along with 239 scientists, appealed to the WHO to reevaluate their stance. 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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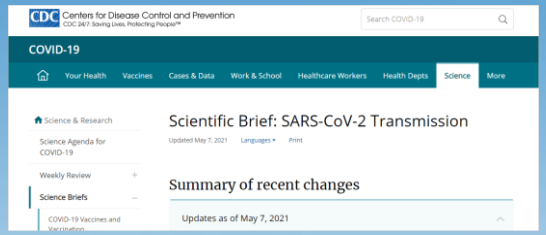
EPA and CDC & White House: IAQ Statements

The New York Times
(May 7, 2021)



"The virus is an airborne threat, the CDC acknowledges"

CDC & ASHRAE: COVID-19 Transmission

- **SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids**
- People release respiratory fluids during exhalation (e.g., quiet breathing, speaking, singing, exercise, coughing, sneezing) in the form of droplets across a spectrum of sizes.
- These droplets carry virus and transmit infection.

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EPA and CDC & White House: IAQ Statements

(Posted: May 7, 2021)

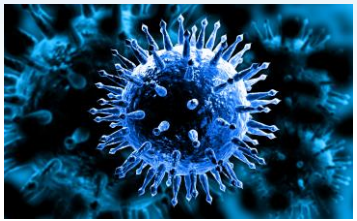
- **Transmission of SARS-CoV-2 from inhalation of virus in the air farther than six feet from an infectious source can occur**
  - "…factors that increase the risk of SARS-CoV-2 infection …:
    - **Increased Exhalation** …infectious person is engaged in physical exertion
    - **Prolonged exposure** to these conditions, typically more than 15 minutes
    - **Enclosed spaces with inadequate ventilation …** the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space

EPA and CDC & White House: IAQ Statements

Environmental Protection Agency (EPA)

Indoor Air and Coronavirus (COVID-19)

- "**Spread of COVID-19 occurs via airborne particles** and droplets…"
- "…People who are infected with COVID can release particles and droplets of respiratory fluids that contain the SARS-CoV-2 virus into the air…"
- **"These droplets carry the virus and transmit infection."**



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EPA and CDC & White House: IAQ Statements

White House: October 11, 2022: Clean Air In Buildings

- "…**improving indoor air quality within the buildings** we use every day is an essential part of the Biden Administration's plan to manage COVID-19 this fall and winter."


THE WHITE HOUSE

Administration Priorities COVID Plan Briefing Room Español

OCTOBER 12, 2022

Readout of the White House Summit on Improving Indoor Air Quality

BRIEFING ROOM • STATEMENTS AND RELEASES

In addition to new, updated COVID-19 vaccines and lifesaving treatments, improving indoor air quality within the buildings we use every day is an

- "Yesterday , the White House hosted a Summit on Improving Indoor Air Quality, bringing together public health and ventilation **experts…to highlight the benefits of improved indoor air quality in mitigating the spread of COVID-19**…"
- "Encouraging businesses and organizations around the country in taking the **Clean Air in Buildings** Challenge."

- "Making it easier for schools to improve indoor air quality
- **Lifting up organizations who are leading the way on indoor air quality in their buildings."**

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EPA and CDC & White House: IAQ Statements

White House: Clean Air in Buildings Challenge

- **About the Challenge:**
- " The quality and cleanliness of the air we breathe everyday has a significant impact on our health and well-being."
- **"Better indoor air quality is a powerful tool in preventing the spread of COVID-19 and other infectious diseases.."**

- **The Clean Air in Buildings Challenge is a call to action** for organizational leaders and building owners and operators of all types to assess their indoor air quality and make ventilation, air filtration, and air cleaning improvements to help keep building occupants safe.

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EPA and CDC & White House: IAQ Statements

White House: Clean Air in Buildings Challenge

About the Challenge: 4 Key Commitments

- **Commitment #1: Create a Clean Indoor Air Action Plan**:
  - Create a plan for upgrades and improvements, including HVAC inspections and maintenance if applicable
- **Commitment #2: Optimize Fresh Air Ventilation**
  - **Bring clean outdoor air indoors and circulate it when it is safe to do so.**
- **Commitment #3: Enhance Air Filtration and Cleaning**
  - By taking steps such as improving your central HVAC system and/or installing in-room air cleaning devices including HEPA filters
- **Commitment #4: Engage the Building Community**
  - Communicate with building occupants to increase awareness, commitment, and participation.

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EPA and CDC & White House: IAQ Statements

Lessons Learned:

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Air Quality, Contaminants & CO2

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Air Quality, Contaminants & CO_2

Ventilation and the Risk of Infection:

- **May 7, 2021:** "…**SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids**."
- "…Infectious exposures to respiratory fluids carrying SARS-C0V-2 occur in three principle ways…deposition, touching, and **inhalation of air carrying very small droplets and aerosol particles that contain infectious virus**."

CDC Website Subsequent Statement

- *"When indoors, **ventilation mitigation strategies** can help reduce viral particle concentration."*
- *"Open outdoor air damper beyond minimum settings to reduce or **eliminate HVAC air recirculation**."*

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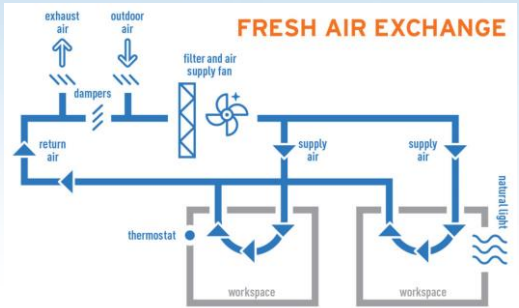
Air Quality, Contaminants & CO_2

Ventilation and the Risk of Infection: EPA: Clean Air in Buildings Challenge

- Section #2: **Optimize Fresh Air Ventilation…:**
  - "Ensure outdoor air is acceptably clean or is adequately filtered as it is brought into the building



Fact Sheet Guidelines:

- "Run HVAC systems during all occupied hours to ensure clean air enters and is distributed throughout the building."
- **"Increase volume of clean, outdoor air at times of higher risk. (e.g. at times of elevated risk of COVID-19).**
- "Consider running the HVAC system to refresh air before arrival and/or remove remaining particles at the end of the day (e.g., 1-2 hours before/after the building is occupied,) as needed."

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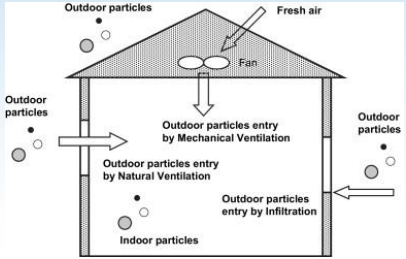
Air Quality, Contaminants & CO_2

Contamination Levels & CO_2:

Outdoor and Indoor Air Contaminants: Comparison

Indoor Air Pollutant

- Asbestos
- Biological Pollutants
- Carbon Monoxide
- Cook Stoves
- Formaldehyde/Pressed Wood Products
- Lead
- Nitrogen Dioxide
- Pesticides
- Radon
- Particulate Matter (PM)
- Volatile Organic Compounds
- Wood Smoke



Outdoor Air Pollutant

- Carbon Monoxide
- Lead
- Nitrogen Dioxide
- Ozone
- Particulate Matter (PM):Various Sizes
- Sulfur Dioxide)

(Note: Outdoor air contains other pollutants not regularly monitored by the EPA)

Indoor Air Includes Outdoor Air Contaminants!

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Air Quality, Contaminants & CO_2

Contamination Levels and CO_2:

- "EPA studies of human exposure to air pollutants indicate the **indoor levels of pollutants may be two to five times –** and occasionally more than 100 times **– higher than outdoor levels."**

ASHRAE Journal: June 2022

- "CO_2 is a stoichiometric by-product of both hydrocarbon fuel combustion and biological metabolism…"
- **"…measuring CO_2 concentration offers an easy … way to gage the concentration of the other pollutants."**

(*Revisiting the CO_2 Limit:* By Robert Stumm, P.E.)

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Air Quality, Contaminants & CO_2

Contamination Levels and CO_2:

- **Robert Stumm, P.E.:** "Suggested here is that some **statistical correlation may exist between the concentration of CO_2 and that of the aggregate of other by-product pollutants** affecting human comfort and wellness."

(By: Robert E. Stumm, P.E.)

Phoenix: Research Gate 2013 Report

ResearchGate

- "…the presence of an **"urban CO_2 dome" that reaches 555 ppm** in the city center and decreases to…~370 ppm on the outskirts."

ASHRAE Standard 62.1-1999:

- Satisfactory Indoor CO_2 Limit of 700 ppm above outdoor CO_2 Concentrations (Based on Outdoor CO_2 Concentrations in the 1980's of **~350 ppm**.)
- **Urban Phoenix: 555 ppm + 700 = 1255 ppm indoor CO_2**

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Air Quality, Contaminants & CO_2

Contamination Levels and CO_2: ASHRAE Journal: June 2022

- Phoenix CO_2 Urban Dome in 2021?

Phoenix CO_2 Dome July 2021 = 575 ppm

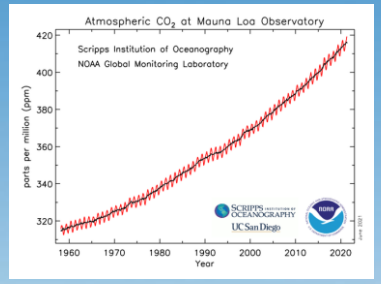
Boston University Study: Between 1990 to 2017:

CO_2 Increase of 291%

TABLE 1 Nominal daily maximum CO_2 levels (ppm) at select urban sites compared with Mauna Loa values.

SITE	DATA YEAR	MAUNA LOA	URBAN	DIFFERENCE
Phoenix, Ariz.	2000	369	575[12]	206
Baltimore	2006	382	488[13]	106
Evanston, Ill.	2011	392	440[14]	48
Los Angeles	2015	400	622[15]	222

Mauna Loa Data from Reference 8. Data current as of July 2021.



(Scripts Institute of Oceanography: NOAA Global Monitoring Laboratory)

CO_2 [ppm]	Air Quality
2100	BAD Heavily contaminated indoor air Ventilation required
2000	
1900	
1800	
1700	
1600	
1500	MEDIOCRE Contaminated indoor air Ventilation recommended
1400	
1300	
1200	
1100	
1000	FAIR
900	
800	GOOD
700	
600	EXCELLENT
500	
400	

(Indoor Quality CO_2 Website)

Robert Stumm Article: Conclusions

- "…substantial evidence of **acute exposure to CO_2 at levels as low as 1,000 ppm** inducing significant **reductions in cognition and decision-making abilities**."
- "Considering the recent studies showing CO_2 directly impacting human health, in particular cognition and decision-making, the **indoor CO_2 level of 1,000 ppm reappears as a sensible, time-honored upper limit**…

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The Indoor Environment:

The Importance of Ventilation & IAQ

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The Indoor Environment

ASHRAE: Epidemic Task Force

- 3.1 Varying Approaches for Facility Type
  - "…healthcare facilities now **use multiple modalities simultaneously** (measures that are referred to as *infection control bundles)…"*
  - **Why? There is no single effective method to remove infection risk**

Table 7.1 Design Parameters—Hospital Spaces

Function of Space	Pressure Relationship to Adjacent Area (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

ASHRAE 170-2017 Guidelines

- In healthcare facilities…intervention for limiting airborne transmission emphasize personnel education and surveillance of behaviors such as hand washing…etc.
- Relative Humidity Varies per Room Served (20-60% RH)
- **Outdoor Air Change Rates:** Vary per Room Served (2-4 ACH)
- **Room Ventilation Air Change Rates:** Vary per Room Served
  - Patient Rooms 4-6 ACH per Diffuser Group Applied
  - Airborne Infection Isolation (AII) Rooms: 12 ACH
  - Operating Rooms; 20 ACH

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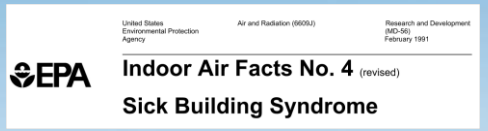
The Indoor Environment

The Importance of Ventilation & IAQ:

***Indoor Air Facts No.4: Sick Building Syndrome* (1991)**

- **Introduction:**
  - "The term **"sick building syndrome" (SBS)** is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building



- **Causes of Sick Building Syndrome:**
  - As a result of the 1973 oil embargo, building **OSA saw a reduction of ventilation to 5 CFM per occupant.**
  - "**Inadequate ventilation,** which may also occur if heating, ventilating, and air conditioning (HVAC) systems do not effectively distribute air to people in the building, is thought to be an **important factor in SBS**."

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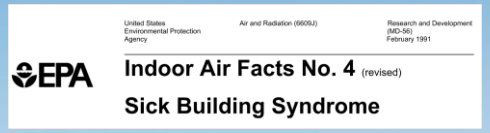
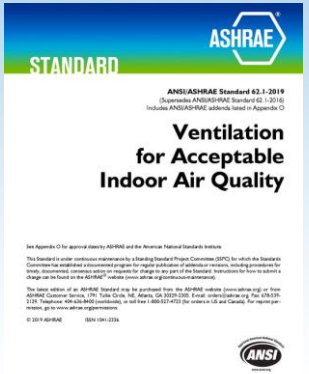
The Importance of Ventilation & IAQ:

- **Causes of Sick Building Syndrome: (1991)**
  - "…the American Society of Air-Conditioning Engineers (ASHRAE) recently revised its ventilation standard to provide a minimum of 15 cfm of outdoor air per person **(20 cfm/person in office spaces)**."



ASHRAE Standard 62.1-2016: Outdoor air rates

- **Office Spaces: 5 cfm/person**
- **Classrooms: 10 cfm/person**



ASHRAE: Epidemic Task Force Review

- Provide and maintain at least required minimum outdoor airflow rates
- Increase outdoor air ventilation … **open outdoor air dampers to 100% as indoor and outdoor conditions permit.)**

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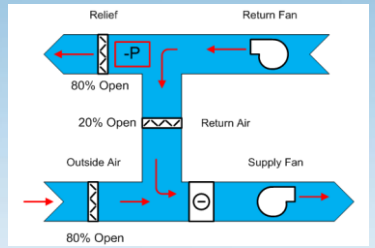
The Importance of Ventilation & IAQ:

- **The Challenge:**
  - Are building **package rooftop unit outside dampers set to allow code minimum outside air** to a building?
  - Are variable air volume (VAV) systems **modulating outside air dampers open to maintain outside air mass flow rates** at part load conditions?
  - Are air handlers designed to increase outside air rates to remove building contaminant concentrations: purge mode?



- **When are buildings at part load conditions?**
  - **Fall, Winter and Early Spring**
  - **Reduced Airflow:** Is the code minimum amount of OSA delivered to each zone?

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The Indoor Environment:

ASHRAE: Ventilation-Related Strategies

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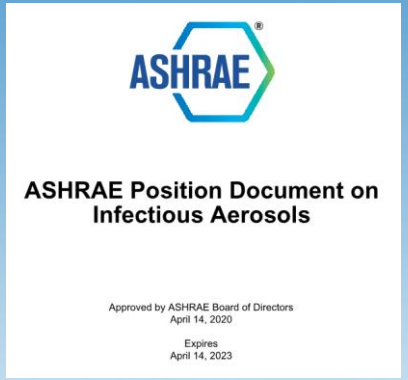
The Indoor Environment

ASHRAE Epidemic Task Force: "Ventilation - Related Strategies"



- **Dilution**
- **Airflow Patterns**
- Pressurization
- Temperature
- **Humidity Distribution & Control**
- Filtration
- **Ultraviolet Light Germicidal Irradiation (UVGI)**

HVAC Factors for Healthier Environments:

- **"Emerging" Technology: Passive Ionization**

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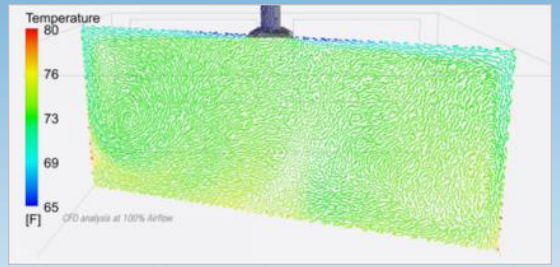
ASHRAE: Ventilation-Related Strategies



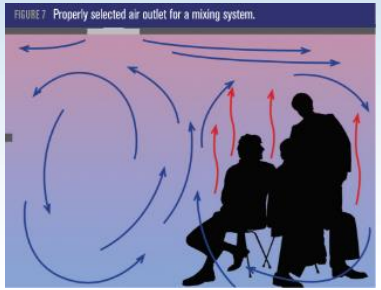
(Acutherm: Mixed-Air Environment)

Dilution & The “Well-Mixed” Environment

- Reduce concentrations of aerosolized pathogens released into occupied rooms
- To reduce contaminant concentrations, **room air and contaminants must be well mixed**.

Well-Mixed Environment: Air Patterns

- Air handlers supply **maximum design air flow**
- Air Diffusers selected for max air flow (discharge velocity & sound)
- Air Diffusers discharge **supply air at 150 FPM**
- Room air induced into supply air jet for air mixing



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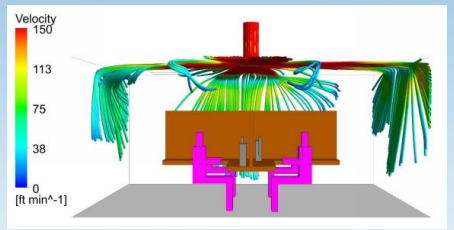
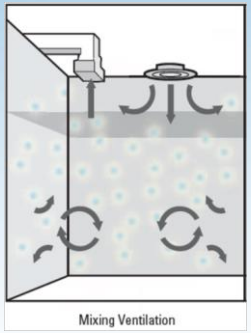
Dilution & The “Well-Mixed” Environment:

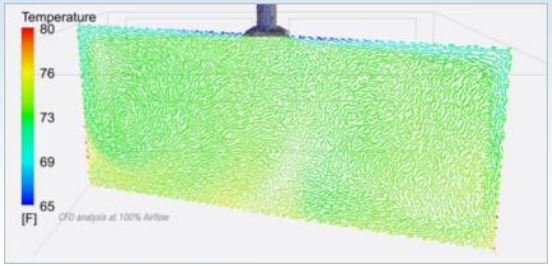
- **Physics of Airflow: Peak Load**
  - Diffusers Supply Maximum Air Flow
  - Maximum airflow = Max Diffuser Discharge Velocity



(Acutherm: Mixed-Air 100% Flow)



- **Uniform Mixing in the Cubic Volume of Space**
- **Uniform Temperature Profile**
- **More “Uniform” Distribution of Contaminants?**



(Acutherm: Mixed-Air CFD)

- **Diffuser Discharge Velocity to be Maintained**
- **Air particles Flow with Air Patterns**

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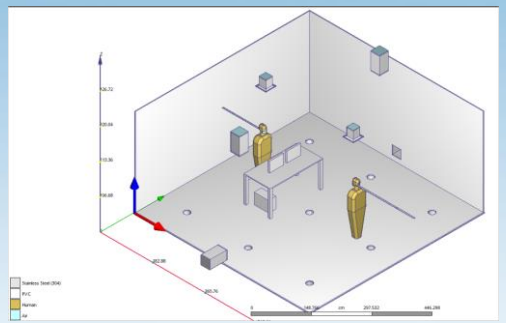
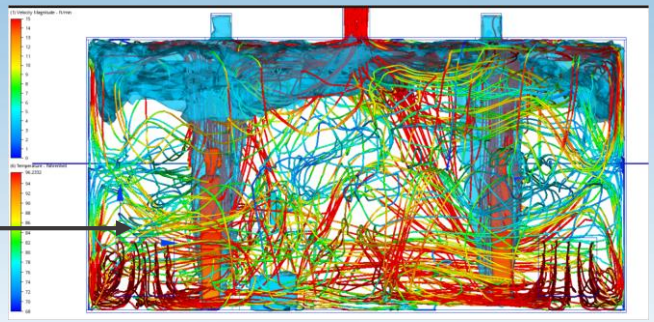
Dilution & The “Well-Mixed” Environment:

- Is the Mixed-Air Environment Well Mixed?
- GLHN Architects and Engineers: CFD Modeling Study



(GLHN: Baseline Room Geometry)

- Air Patterns and Clouds Represent Air Velocity and Temperature regions within the space



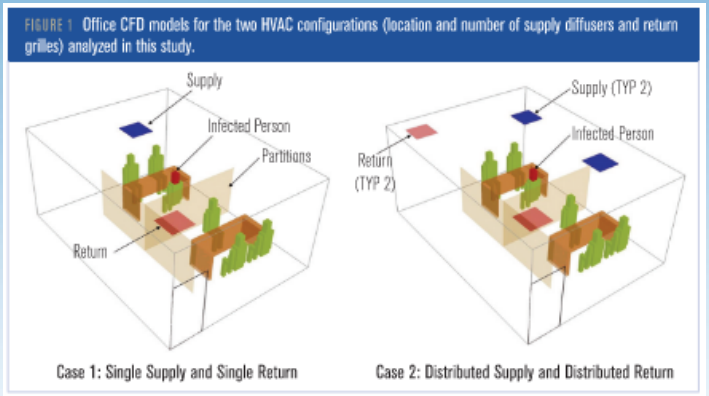
(GLHN: Baseline Geometry CFD)

- CFD model reveals **Room Geometry, Furniture and Occupant Locations** impact effective room air mixing
- **Contaminant Concentrations Can Increase in Areas Where Air Pattern Vortices Occur**

The Indoor Environment

Air Patterns: How Air Moves Within A Space

- ***Analysis Of Spread Of Airborne Contaminants and Risk Of Infection****: ***By Kishor Khankari, PH.D., Fellow ASHRAE*** (ASHRAE Journal, July 2021)



CFD: Room Layout @ 3 ACH

Airflow, Ventilation and CFD

- "**Good ventilation** is commonly referred to…as an increased supply of clean air or **increased air change rate** per hour for enclosed spaces.
- However, **simply increasing the supply of clean air may not be sufficient to achieve good ventilation**"

- **Dr. Khankari:** "In a real situation, **the spatial and temporal variations of airflow patterns** in a space **can result in a non-uniform airflow distribution** which in turn can yield a non-uniform distribution of infection probability."

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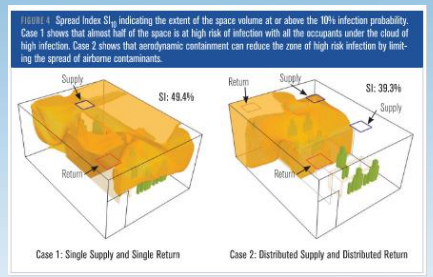
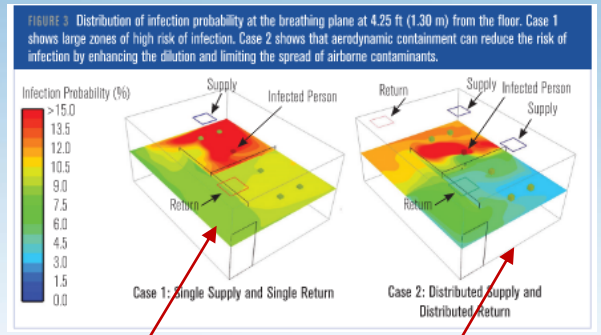
Air Patterns: A Enhanced IAQ Solution?

***Analysis Of Spread Of Airborne Contaminants and Risk Of Infection*: Results and Discussion: (Modified Wells-Riley Equation)**



"In spite of mixing airflow patterns, the **contaminant distribution is not uniform and does not create well-mixed conditions.**"

CFD: Room Layout @ 3 ACH



Greater than 15% Risk **Less than 4% Risk**

(Infection Probability at 4.5 feet AFF)

- **Strategic layout of supply diffusers and exhaust grilles can form the airflow patterns** that can help reduce the risk of contaminant exposure…"
  (*Kishor Khankari, PH.D., Fellow ASHRAE)*

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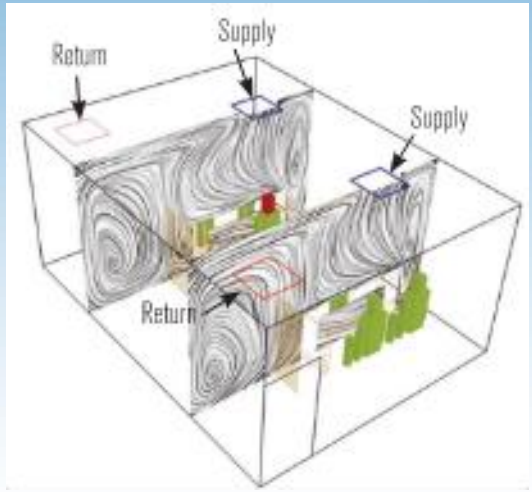
The Indoor Environment

Air Patterns: A Enhanced IAQ Solution?

Analysis Of Spread Of Airborne Contaminants and Risk Of Infection:

- **Summary and Conclusions**
  - "Create a distributed supply layout by **increasing the number of supply diffusers and strategically placing them over the occupied zone.**
  - Create a distributed return layout by increasing the number of exhaust outlets to **create a path of least resistance for the contaminated air to exit the space**.
  - Create an aerodynamic containment by symmetric placement of supply diffusers and return grilles to minimize cross contamination between the symmetric zones of supply and return."

  (Kishor Khankari, PH.D., Fellow ASHRAE)



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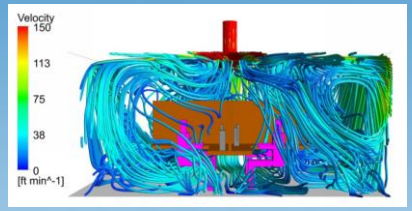
Air Patterns: Part Load Conditions

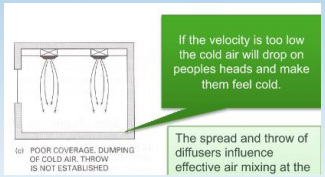
- **Lower Airflow = Partially Mixed Environments**

Does Room Air Mixing Occur?

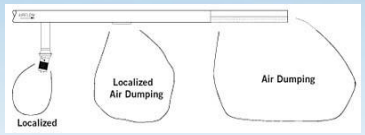


(Acutherm: CFD @ Part Flow)

- **Lower Room Load:** Less supply air required to satisfy thermostat
- Thermostat calls for less air; **VAV boxes modulate to minimum** position**.**



Dumping



(ACHR News)

- Lower volume of supply air = **lower diffuser discharge velocity**
- Cold air **"negative buoyancy"** (cold air falls) exceeds supply air jet and ambient pressure differential

When are Buildings at Part Load Conditions:

- **Autumn, Winter & Early Spring**

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Air Patterns: Air Distribution Layout:

Advantages:

- CFD modeling shows more effective exhaust of room air through more return grilles & location
- A method for enhancing room air dilution
- Good retrofit solution for existing buildings
- Potentially lowest first cost solution

Disadvantages:

- Effectiveness of contaminant removal at part load conditions?
- No energy efficiency advantage

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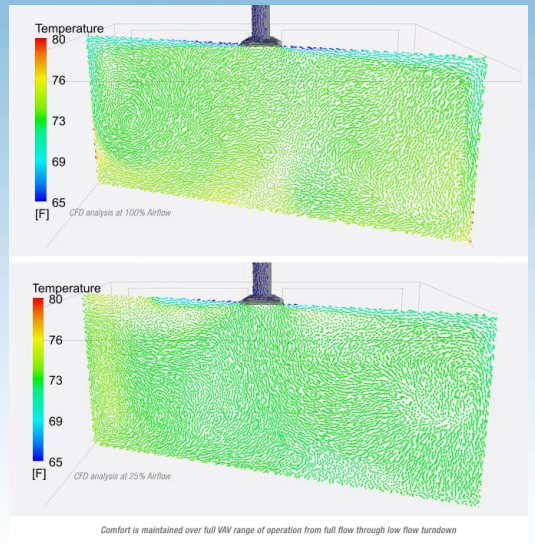
Air Patterns: Ceiling Mounted VAV Diffusers

Room Air Dilution at Low Flow: Mixing Maintained

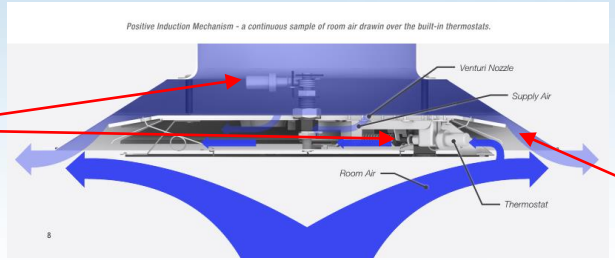
- **Low Pressure VAV :**
  - VAV diffusers maintain discharge velocity even at 25% of design flow
  - Room air is continuously induced into the supply jet at 25% of flow for best low flow mixing.

(100% Flow)



(25% Flow)

Thermal Actuators



Mechanical or DDC Operation

Modulating Vanes

Diffuser Free Area Modulates Open/Closed to Maintain Discharge Velocity

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Air Patterns: Ceiling Mounted VAV Diffusers

Advantages:

- More effective dilution of room air at part load condition
- Low pressure variable volume system design for increased energy efficiency: ~20% - 25%
- Mechanically controlled for ease and simplicity of installation and maintenance
- Opportunity for low first cost (Mechanical Operation, Reduced Maintenance and Control Savings)

Disadvantages:

- Low pressure VAV systems may require larger duct work
- Validation OSA reaching each zone

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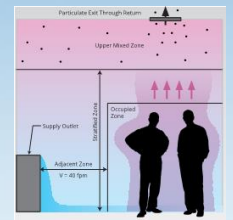
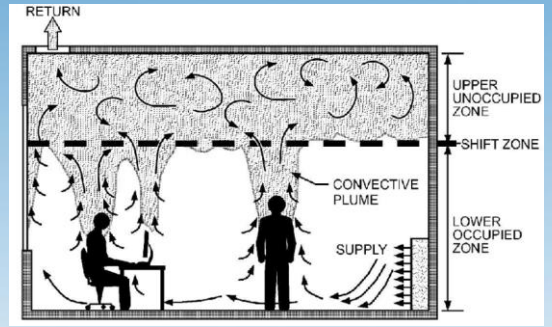
Air Patterns: Displacement Ventilation

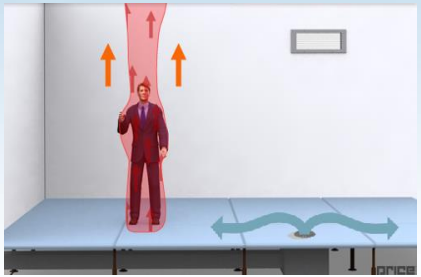
- **62-68°F supply air**
- **80-85°F return air**
- High level returns
- Temperature rise head to foot:
  - Seated – 3.5 deg F
  - Standing – 5 deg F



(Air Patterns: Displacement Ventilation)



(ResearchGate: Convective Plumes)



(AirFixture: UFAD Displacement Ventilation)

- **Warm contaminated air rises out of the breathing zone** to the upper levels of a room
- **Single Pass of Clean Conditioned Air** Across Occupant Breathing Zone

UFAD Air Systems: A Piston of Clean Air from Floor to Ceiling

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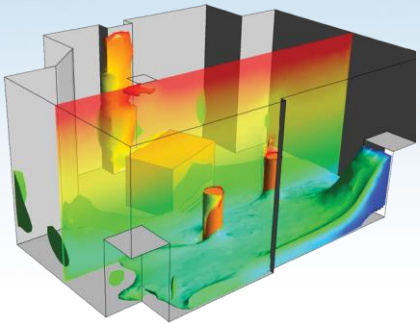
Air Patterns: Displacement Ventilation

- **Create Thermally Stratified Environments**
  - **Convection:** Warm Air Rises / Cold Air Falls
  - Heat Sources in a Room Create Thermal Plumes
  - Thermal Convective Plumes Drive air to Upper Room Level to be Exhausted



KRUEGER
Excellence in Air Distribution

Principles of Convection: Heat drives the air, not fan energy

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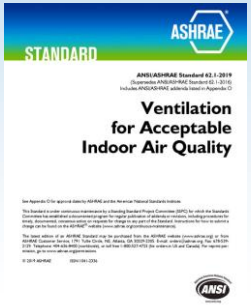
Air Patterns: Displacement Ventilation

ASHRAE Standard 62.1-2016

- **Zone Air Distribution Effectiveness:** "the ratio of the change of contaminant concentration between the air supply and air exhaust to the change of contaminant concentration between the air supply and the breathing zone.



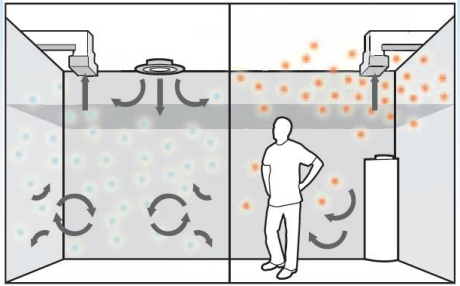


Table 6-4 Zone Air Distribution Effectiveness

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

(New)

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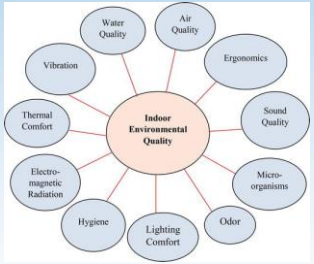
Air Patterns: Displacement Ventilation

Thermal Stratification & Air Movement

- Move the Same Amount of Air in a Room During Peak and Park Load Conditions.
- Why? Temperature Differentials (Surface Temp vs. Room Temp)

Mixed Air

Displaced Air



Indoor Environmental Quality?

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Air Patterns: Displacement Ventilation

Advantages: Low In-Wall Design

- Single pass of clean conditioned air across building zone
- 1.2 zone distribution effectiveness
- Space airflow is the same during peak and part loads
- Low pressure system design for energy efficiency
- Economizer hours double for enhanced energy efficiency
- Adaptive to architectural designs
- Quiet operation
- Superior thermal comfort

Advantages: UFAD Design

- Same advantages as low in-wall design, but…
- More competitively priced than low in-wall
- Single piston of upward moving clean air from floor to upper levels
- 100% OSA system ventilation solution
- UFAD displacement significantly reduced building ductwork

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Air Patterns: Displacement Ventilation

Disadvantages: Low In-Wall Design

- Higher first cost
- Deeper interior walls for supply air ductwork
- Maximum 30 feet distance required for DV diffusers in larger zones

Disadvantages: UFAD Design

- Early design guidelines resulted in less than ideal performance
- May cost more than conventional HVAC depending on building type
- Building sub-trades to be educated on UFAD and the need for plenum integrity

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The Indoor Environment:

Humidity Control

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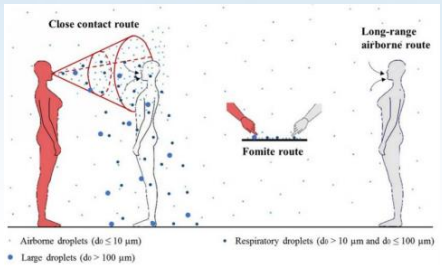
Humidity Control: Maintaining Moisture Levels

- **Proper Space Humidification**
  - ASHRAE and related humidification studies have determined the role of humidity in reducing risk of airborne transmission
  - The impact of humidity on human immune systems
  - Reduce the release rate of aerosolized pathogens from virally loaded droplets



(Virally Loaded Droplets Dispersion)

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Humidity Control: Risk of Infection Impact

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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Humidity Control: Risk of Infection Impact

References: Section 3.3: Temperature & Humidity

- **(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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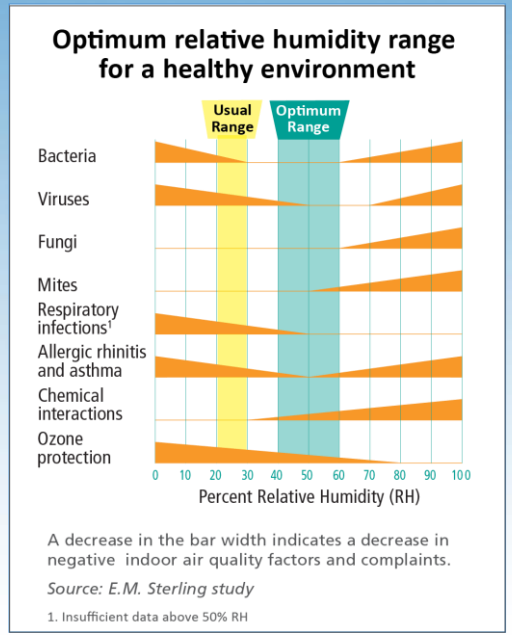
Humidity Control: Risk of Infection Impact

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



- **The influenza virus, for example…become less viable as the relative humidity increased above 40%...**infectiousness of influenza virus increased as the relative humidity decreased below 40%...

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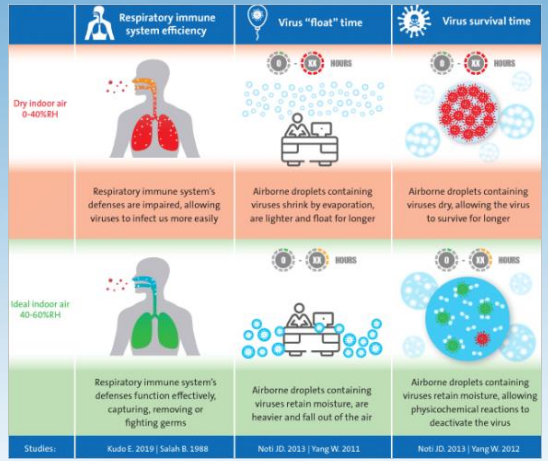
Humidity Control: Risk of Infection Impact



- **ES Magazine: May 5th, 2020**
  - **Dr. Stephanie Taylor Petitions the World Health Organization for 40% - 60% RH Policy**
    - "There is now **overwhelming scientific evidence** that a mid-range air humidity has significant benefits for human health."
    - "The time has come for regulations on indoor air quality to include a humidity level of 40% - 60% RH."

- **Phoenix, Arizona: Driest Time of Year?**
  - **Coldest Times of the Year: Fall, Winter and Early Spring**
  - **FACT:** Air on a Phoenix June day of 115F DB at 15% RH has **more moisture** than an indoor air condition of 75F DB @ 50% RH

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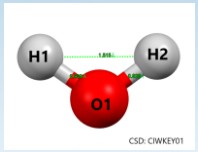
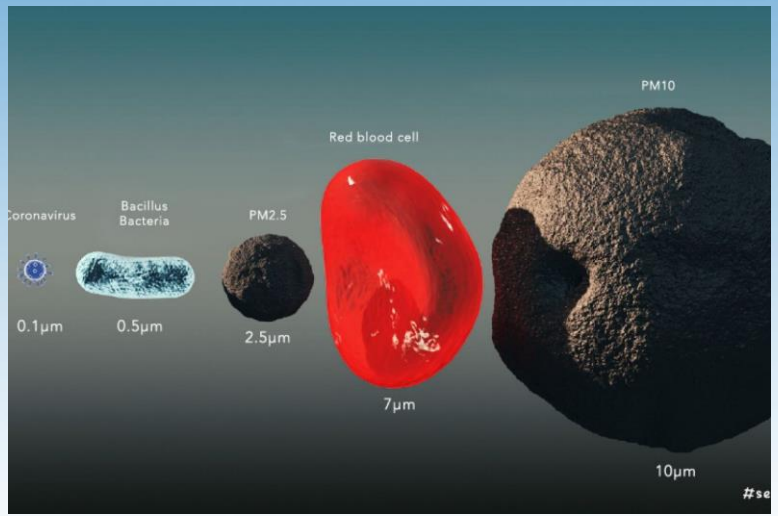
Humidity Control: Risk of Infection Impact

Aerosolization & Precipitation: Droplet Size, Buoyancy & Float Time

SARS-CoV-2 = ~0.125 microns



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



Desiccated Airborne viruses are Released from Expiratory Droplets: Breathing, Talking, Coughing or Sneezing

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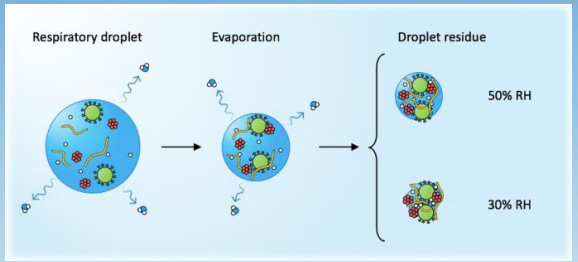
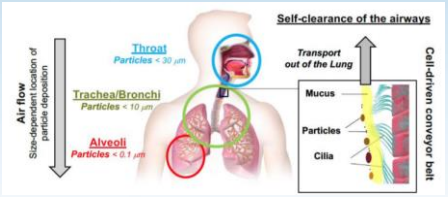
Humidity Control: Risk of Infection Impact

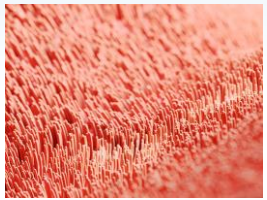
Maintaining Humidity Levels Results in:

- **Reducing virally loaded droplet desiccation rates** releasing active pathogens into a space
- Virally loaded droplets maintain size longer allowing them to fall out of the air more quickly.



(Springer: *Relative humidity in droplet and airborne transmission of disease*)





- **Ingested virally loaded droplets** are more likely to be captured by the wet surfaces of the mouth, nose and esophagus prevent deep inhalation
- **Immune systems are more efficient in** resisting and expressing ingested pathogens as mucus flow from lungs to expiratory orifices more freely

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Humidity Control: Risk of Infection Impact

Advantages:

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

Disadvantages:

- Cost of Installation and Piping
- Maintenance
- RO Water Required
- Tight Space Dew Point Control

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The Indoor Environment:

Ultraviolet Germicidal Irradiation (UVGI)

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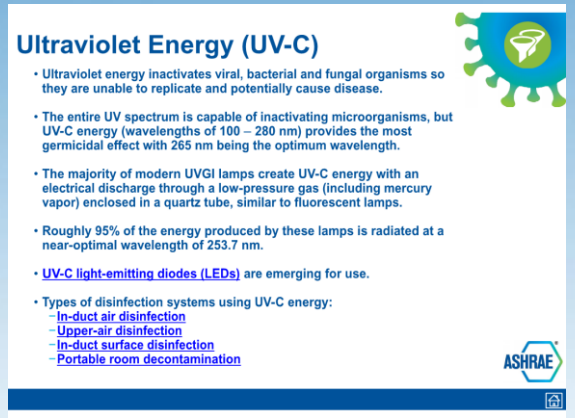
The Indoor Environment

Ultraviolet Germicidal Irradiation (UVGI)

- **Air Disinfection:**
  - **Ultraviolet Germicidal Irradiation (UVGI)** "Ultraviolet energy inactivates viral, bacterial and fungal organisms so they are unable to replicate and potentially cause disease."



COLUMBIA UNIVERSITY
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Columbia University – UV/SARS-CoV-2 Study

- "…ongoing studies…indicate that "UV is very efficient for killing this virus."

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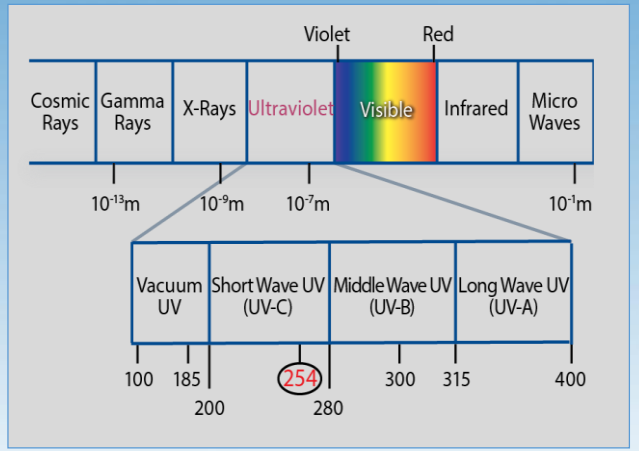
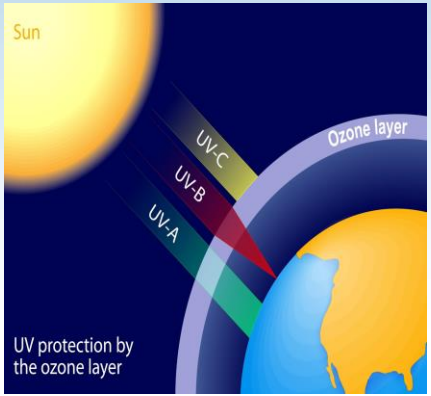
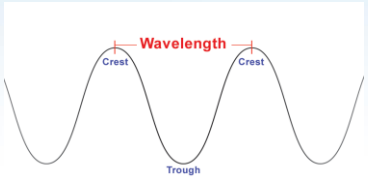
Ultraviolet Germicidal Irradiation (UVGI)

- **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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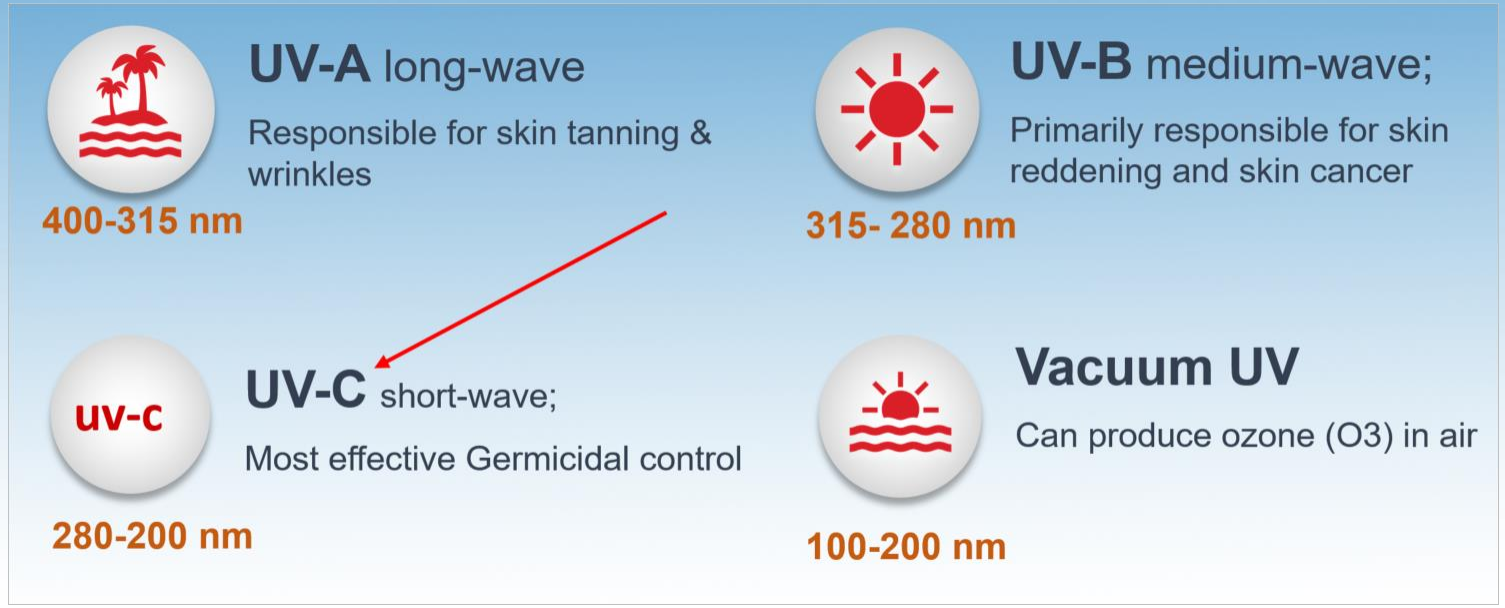
Ultraviolet Germicidal Irradiation (UVGI)

- **Levels of Ultraviolet Light:**



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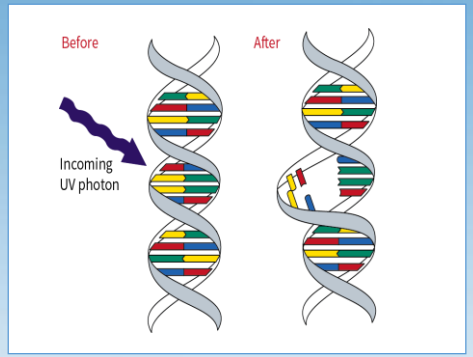
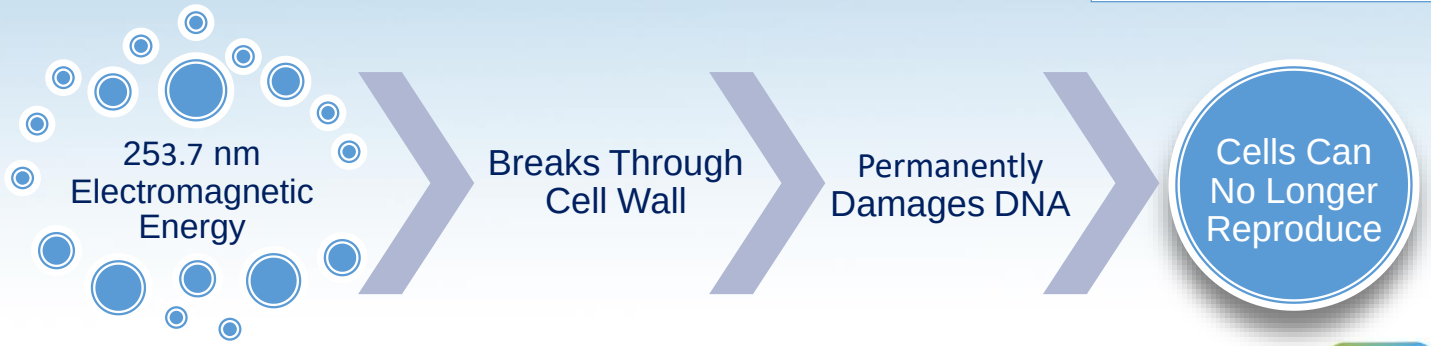
Ultraviolet Germicidal Irradiation (UVGI)

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”)





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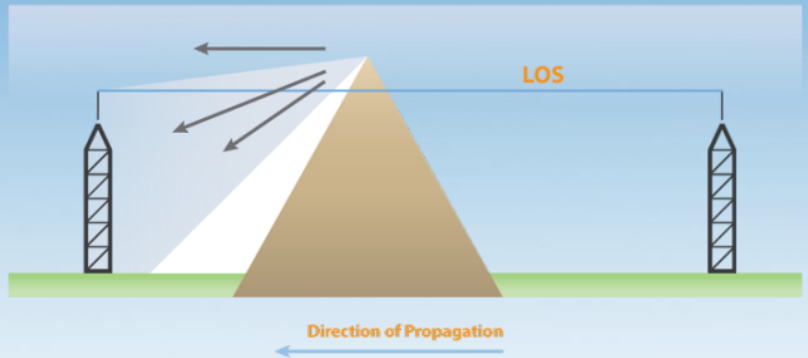
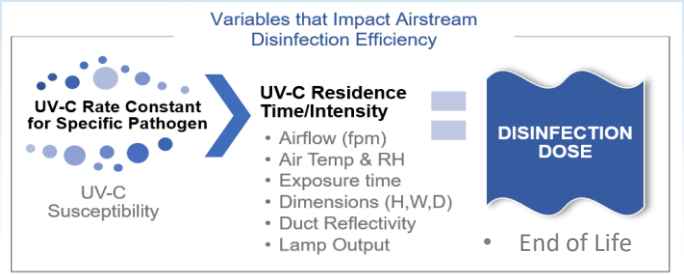
Ultraviolet Germicidal Irradiation (UVGI)

- 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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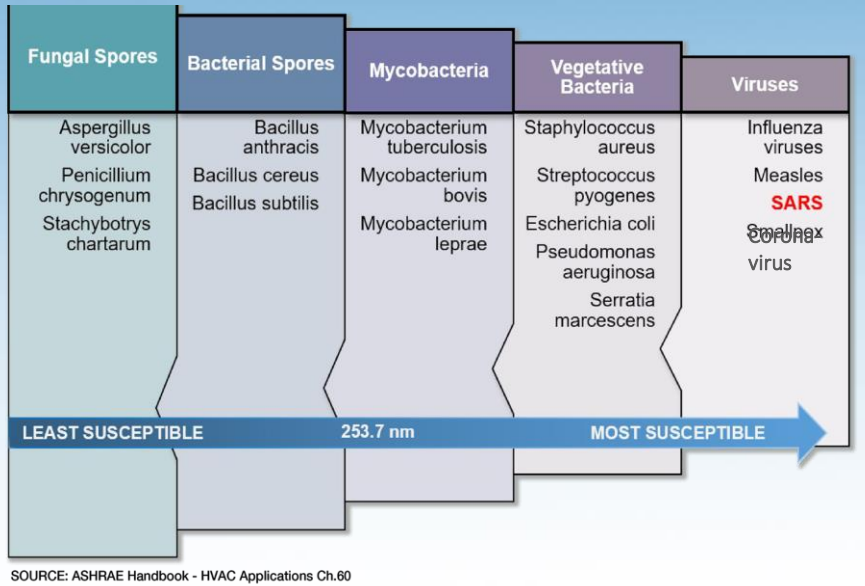
Ultraviolet Germicidal Irradiation (UVGI)

Pathogen Susceptibility to UV-C Light

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



SOURCE: ASHRAE Handbook - HVAC Applications Ch.60

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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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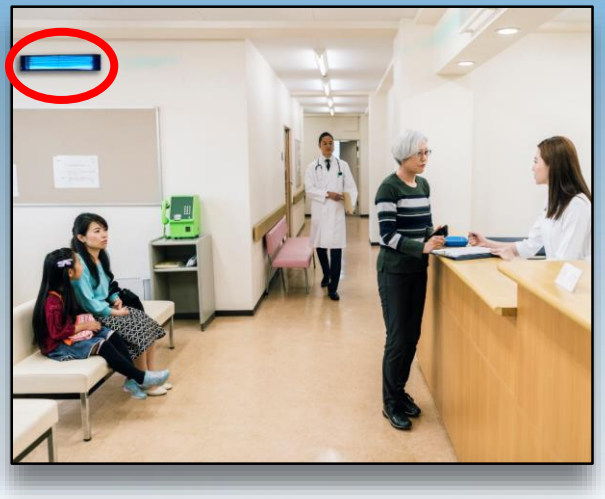
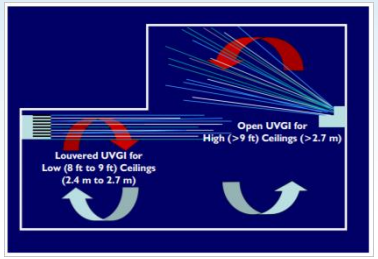
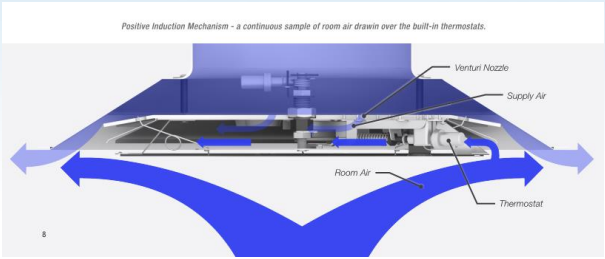
Ultraviolet Germicidal Irradiation (UVGI)

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







- **The VAV Mixed-Air Challenge: Part Load? VAV Diffusers**

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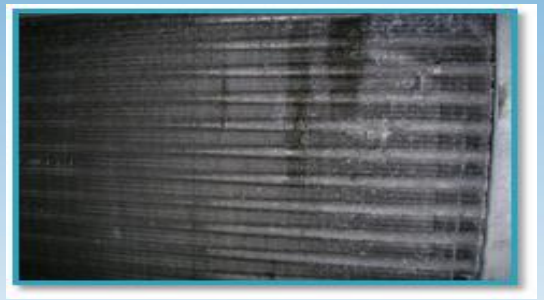
Ultraviolet Germicidal Irradiation (UVGI)

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) by reducing the release of bio-agents from coils and neutralizes airborne pathogens

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The Indoor Environment

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
- No conclusive testing for SARS-CoV-2

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The Indoor Environment:

Needle Point Bi-Polar Ionization

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The Indoor Environment

Needlepoint Bi-Polar Ionization: Emerging Technology

Steady-State Ionization

- High voltage of both polarities continuously applied to a pair of positive (+) and negative (-) emitter points.
- Electrostatically charged particles (ions) are produced resulting in an electrostatic field
- **This process is known as Bi-Polar Ionization.**

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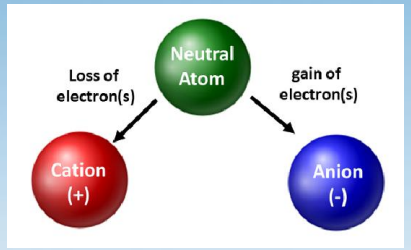
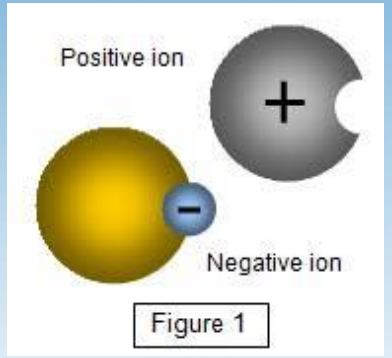
Needlepoint Bi-Polar Ionization: Emerging Technology

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
- **Active Ionization:**
  - Ions created that act upon and **decouple molecular bonds**



- **Passive Ionization:**
  - Generating an electrostatic field through which particles pass and assigns either positive and negative charges

- **Forces of Attraction:**
  - Particles of opposite charges attract each other and come together to create a neutral charge

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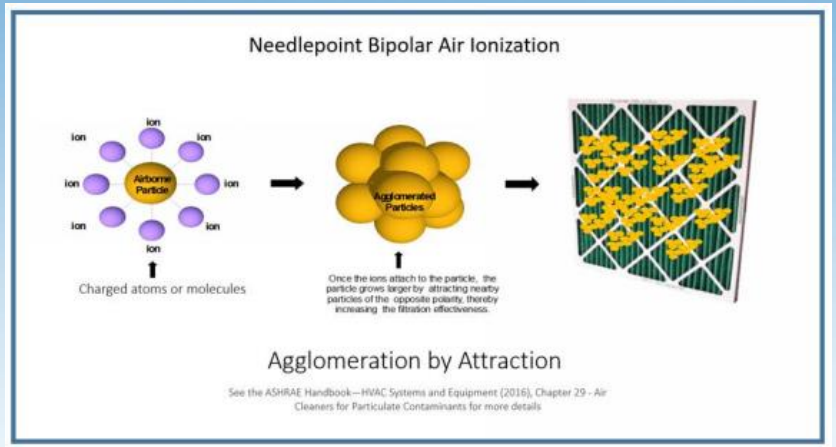
Needlepoint Bi-Polar Ionization: Emerging Technology

Agglomeration

- Electrons added or removed from larger particles assigns either a positive or negative electrical charge.
- Particles electrostatically bond and become larger and more massive
- Larger particles drop out of the air more quickly (gravity)
- Larger particles allow for more effective filtration



- **MERV-8 filtration can approach the efficiency of MERV-13 filters.**
- **Energy Efficiency:** Maintaining filter effectiveness by using lower MERV rating filters. Less statice pressure across media

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The Indoor Environment

Needlepoint Bi-Polar Ionization: Emerging Technology

CDC Position on Emerging Technologies for Air Cleaning

- **ASHRAE consulted with CDC regarding the use of Bipolar Ionization and other emerging technologies and received the following guidance:**

"CDC does not provide recommendations for, or against, any manufacturer or manufacturer's product.

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 (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners) 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, only that in the absence of an established body of evidence reflecting proven efficacy under as-used conditions, 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 homework. Consumers should research the technology, attempting to match any specific claims against the consumer's intended use. Consumers should request efficacy performance data that quantitively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology. Preferably, the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources."

CDC Statement:

- "Needlepoint bi-polar ionization has a less-documented track record in regards to cleaning / disinfecting large and fast volumes of moving air within…HVAC systems."
- "This is not to imply that the technology doesn't work … the technology is still considered by many to be an "emerging technology."

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Needlepoint Bi-Polar Ionization: Emerging Technology

- GPS Air: Needlepoint Bi-Polar Ionization

GPS: UL2998
UL compliance for non-ozone generation

The Indoor Environment

Needlepoint Bi-Polar Ionization: Emerging Technology

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 & CDC recognizes ionization is an “emerging technology”

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Energy Efficiency and Enhanced IAQ: Spanning the Divide

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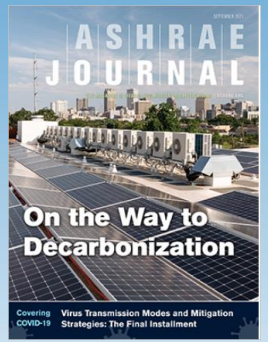
Enhanced IAQ & Energy Efficiency

ASHRAE Journal September 2021



- **Recent Development for Standard 90.1;**
  - "…the **U.S. Department of Energy (DOE)** issued a determination that **ANSI/ASHRAE/IES Standard 90.1-2019** for buildings except low-Rise Residential Buildings, improves energy efficiency in commercial buildings…The **final determination** makes the 2019 version of the standard the reference energy-efficiency standard…"

What's Next for Standard 90.1

ATLANTA–In late July, the U.S. Department of Energy (DOE) issued a determination that ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, improves energy efficiency in commercial buildings compared to the 2016 standard.

The final determination makes the 2019 version of the standard the reference energy-efficiency standard for buildings other than low-rise residential buildings, said Standing Standard Project Committee 90.1 Chair Don Brundage, P.E., Member ASHRAE; Co-Vice Chair Thomas Culp, Ph.D., Member ASHRAE; and special status as the model energy code for buildings within the 90.1 scope."

Now What?

DOE analysis shows the updated standard could cause national savings in commercial buildings of about 4.7% site energy, 4.3% source energy and 4.3% energy cost. States and other jurisdictions are now required to review their commercial building code regarding energy efficiency and update their codes to meet or exceed Standard 90.1-2019. Each state or jurisdiction has their own process for considering updates

US Department of Energy

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Enhanced IAQ & Energy Efficiency

ASHRAE Epidemic Task Force: Ventilation Related Strategies

- **Dilution**
- **Airflow Patterns**
- Pressurization
- Temperature
- **Humidity Distribution & Control**
- Filtration
- **Ultraviolet Light Germicidal Irradiation (UVGI)**

Higher first and operating costs associated with most strategies

- Is there an opportunity to created environments with enhanced IAQ while being more energy efficient. YES!

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Enhanced IAQ & Energy Efficiency

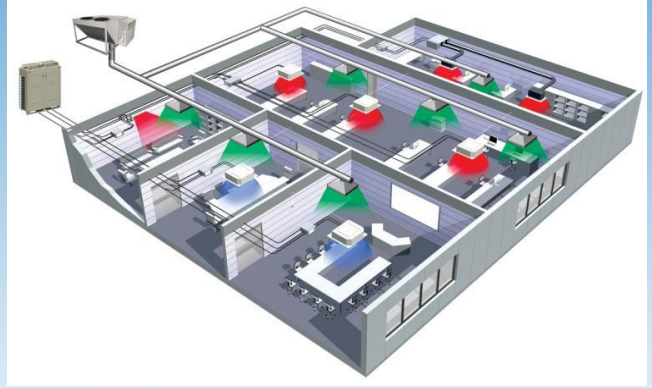
ES Magazine July 2022 Edition

Released July 6th

100% Outside Air VRF Systems: A Sustainable, Hybrid Approach for Superior IEQ

COOLING & CHILLERS

Increasing the amount of outside air to the occupied space and increasing ventilation air change rates are effective solutions for reducing concentrations of contaminants and the risk of infection.



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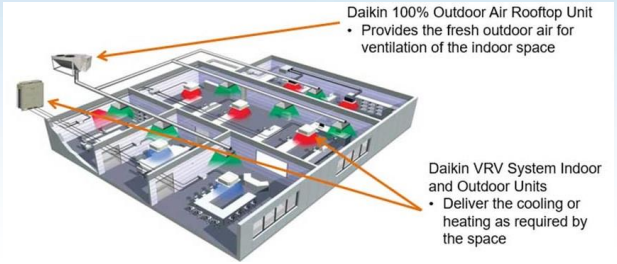
Variable Refrigerant Systems with Decoupled Outside Air Units (DOAS) (28,000 SQFT Medical Office Building)

Building Loads, VRV Equipment Selection Review:

- **VRV Performance: System (DOAS & VRV) Energy Savings**
  - Design #1: Untempered Mixed-Air: **VRV System Total Energy – 108,084 kW/h**
  - Design #2: 100% OSA DOAS: **53.3F DP SA: VRV Total Energy – 87,972 kW/h**
  - Design #3: 100% OSA DOAS: **48.8F DP SA: VRV Total Energy – 80,104 kW/h**



Percentage of Energy Savings:

- Design #1: Base Line Design – 0.0%
- **Design #2: Energy Savings = 19%**
- **Design #3: Energy Savings = 26%**

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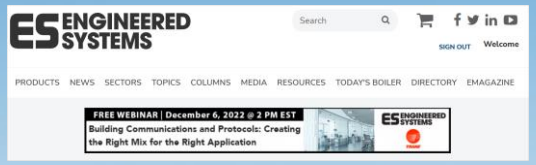
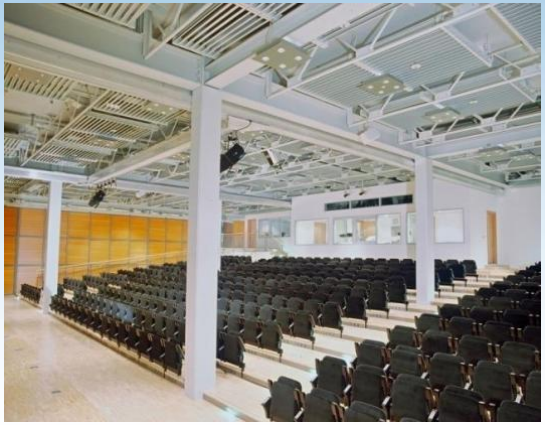
100% Outside Air Passive Radiant Cooling & Heating Systems

- **ES Magazine: December 2022 Publication**



- Total load decoupled into sensible and latent components
- Heat transfer medium? Water for sensible load
- Less system horsepower than conventional HVAC systems



- **System efficiency 30% to 40% greater than medium pressure VAV**

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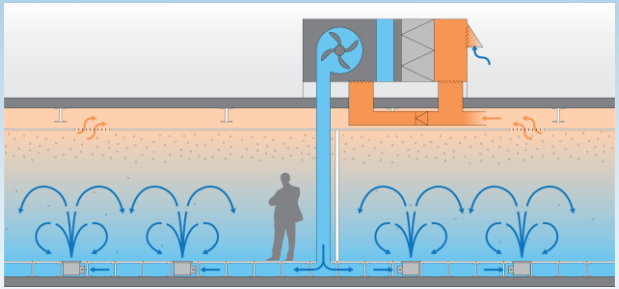
Underfloor Air Systems (UFAD) and Active Chilled Beam Technology

- **Innovative Design Considerations: Not new technologies**



- Single piston of upward flowing clean conditioned air across occupant breathing zones
- 100% OSA decoupled hydronic solutions

- Reduced life cycle costs and flexibility for building remodeling often resulting from building's having to adapt to new floor layouts

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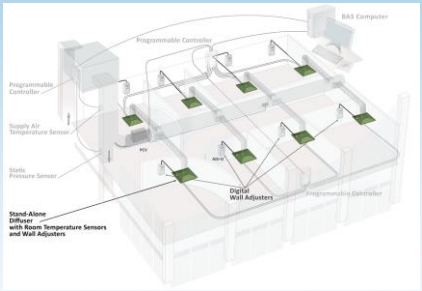
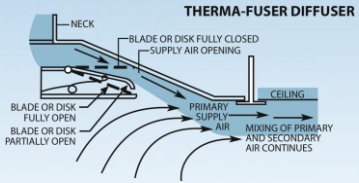
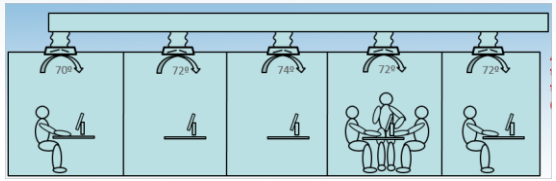
Low Pressure Variable Air Volume Systems

- Provide proper environmental mixing throughout the year, even during part load conditions.
- High occupancy areas served by UV-C light technology mounted in upper levels of a room





- Closer temperature control to each zone
- **Energy efficiency factor 15% to 25%** in reduced fan horsepower
- Attractive first cost solution
- Small and medium size building market



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Concluding Remarks

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Questions?

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Thank you.

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