Mitigating Pathogen Transmission

Part Three: Indoor Air Quality (IAQ), Air Patterns, System Integration

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
  - Standard 62.1 - 2019
- Krueger – Displacement Ventilation
- Acutherm – Low Pressure VAV
- Daikin: Variable Refrigeration Volume
- TWA Panels
- Dadanco Chilled Beams
- 100% OSA Units
  - Annex Air
  - Daikin

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Agenda

- Seminar Review
- Indoor Air Quality
  - ASHRAE Standard 62.1 (2019)
- Air Patterns
  - Mixed Air Systems
  - Full Load vs. Part Load
- System Integration
  - Retrofit
  - New Construction

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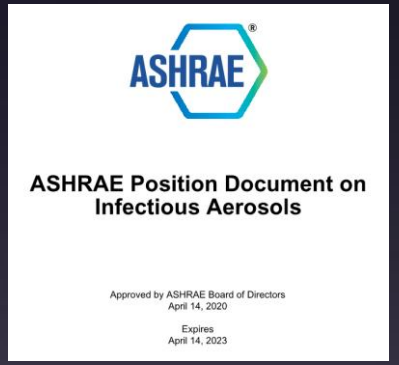
Seminar Review

ASHRAE Epidemic Task Force:

- ASHRAE Position Document on Infectious Aerosols
- TIME Article by Professor Jose-Luis Jimenez
  - **COVID-19 Is Transmitted Through Aerosols. We Have Enough Evidence, Now It Is Time to Act**



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Seminar Review

Center for Disease Control (CDC)

November 2, 2020: Updated Language for Spread of Infection:

Coronavirus Disease 2019 (COVID-19) MENU >

Spread

How does the virus spread? –

- The virus that causes COVID-19 most commonly spreads between people who are in close contact with one another (within about 6 feet, or 2 arm lengths).
- It spreads through respiratory **droplets or small particles, such as those in aerosols, produced when an infected person coughs, sneezes, sings, talks, or breathes**.
  - These **particles can be inhaled** into the nose, mouth, airways, and lungs and cause infection. **This is thought to be the main way the virus spreads.**
  - Droplets can also land on surfaces and objects and be transferred by touch. A person may get COVID-19 by **touching the 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 the main way the virus spreads.
- It is possible that **COVID-19 may spread through the droplets and airborne particles that are formed when a person who has COVID-19 coughs, sneezes, sings, talks, or breathes.** There is growing evidence that droplets and airborne particles can remain suspended in the air and be breathed in by others, and travel distances beyond 6 feet (for example, during choir practice, in restaurants, or in fitness classes). In general, indoor environments without good ventilation increase this risk.

COVID-19 seems to be spreading easily and sustainably in the community ("community spread") in many affected geographic areas. Community spread means people have been infected with the virus in an area, including some who are not sure how or where they became infected.

Will warm weather stop the outbreak of COVID-19? +

CDC states: "It spreads through respiratory droplets or small particles, such as those in aerosols, produced when an infected person coughs, sneezes, sings, talks or breathes…"

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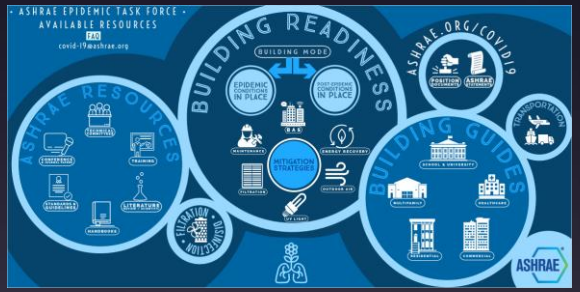
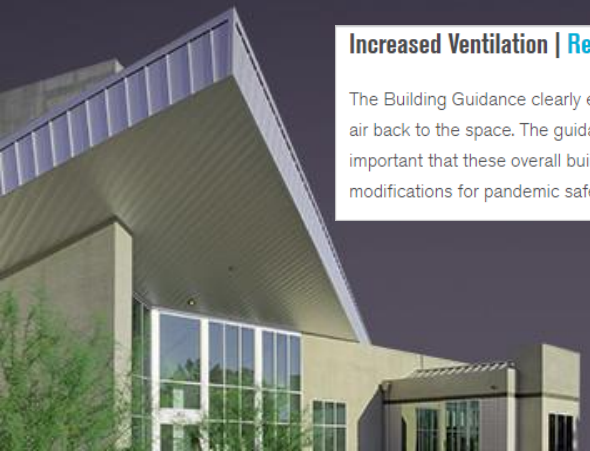
Seminar Review

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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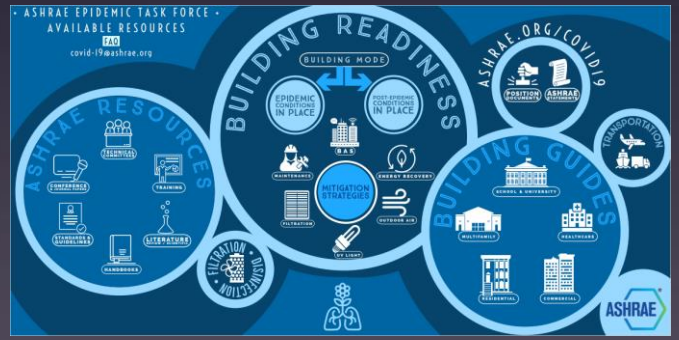
Seminar Review

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

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Seminar Review

ASHRAE Epidemic Task Force: Humidification

Position Document on Infectious Aerosols:

- (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%.

ASHRAE Position Document on Infectious Aerosols

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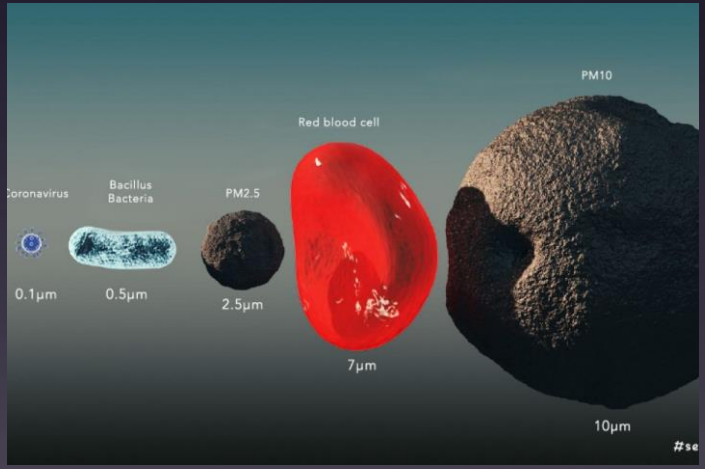
Humidification

ASHRAE Epidemic Task Force: Humidification

Aerosolization & Precipitation: Droplet Size, Buoyancy & Float Time

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



SARS-CoV-2 = ~0.125 microns

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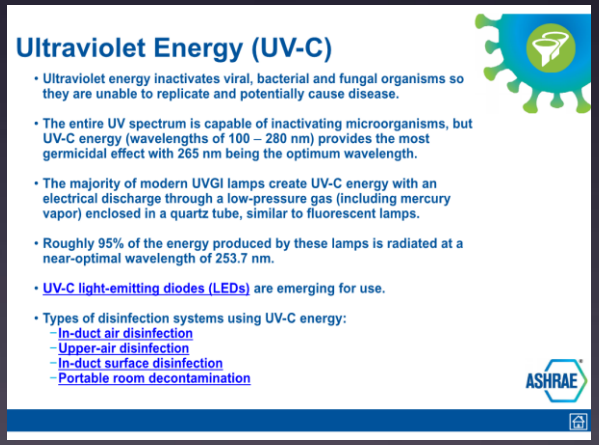
Seminar Review

ASHRAE Epidemic Task Force – Filtration & Disinfection

Ultraviolet Germicidal Irradiation (UVGI)

- 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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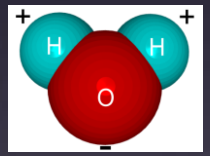
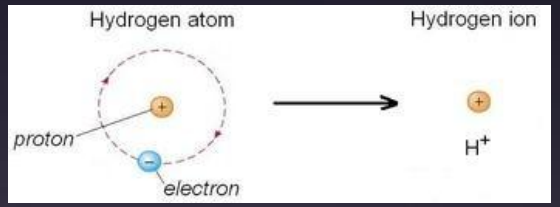
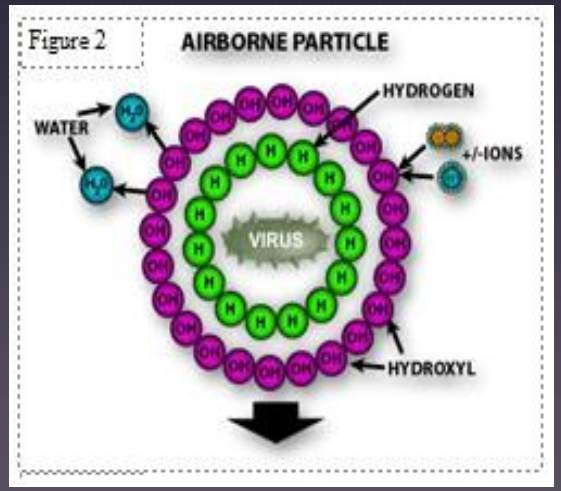
Seminar Review

ASHRAE: Emerging Technology - Ionization

- **Hydrogen & Oxygen ions create an ion plasma field within the built environment**







Germicides Cannot Reproduce

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Questions?

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Indoor Air Quality (IAQ)

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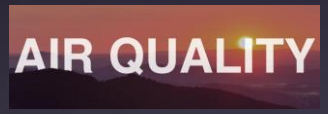
Indoor Air Quality (IAQ)

What is Indoor Air Quality?

Environmental Protection Industry (EPA):



- “Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Understanding and controlling common pollutants indoors can help reduce your risk of indoor health concerns.”

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Indoor Air Quality (IAQ)

What is Indoor Air Quality?

Environmental Protection Industry (EPA):

- Sources of Indoor Air Pollution
  - Building materials
    - Newly installed flooring, upholstery, cabinetry and furniture made of certain pressed wood products
  - Household cleaning products
  - Excess moisture
  - Pesticides

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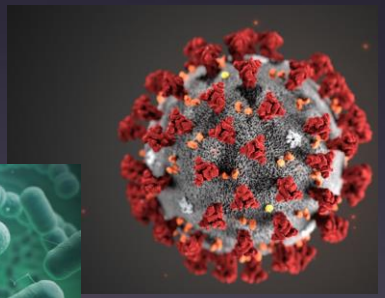
Indoor Air Quality (IAQ)

What is Indoor Air Quality?

Environmental Protection Industry (EPA):

- Sources of Biological Air Pollution
  - Pollens
  - Viruses
  - Mold
  - Bacteria



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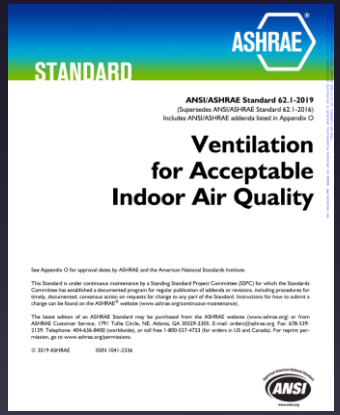
Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 1. Purpose: “This standard is to specify minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects”



{First Published 1973)

- “This standard is intended for regulatory application to new buildings, additions to existing buildings, and those changes to existing buildings that are identified in the body of the standard.”

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Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 3. Definitions:
    - 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.”
      - Supply Air: “air delivered by mechanical system or natural ventilation to a space and composed of any combination of outdoor air, recirculated air, or transfer air.”
        - Ventilation Air: “that portion of supply air that is outdoor air plus any recirculated air that has been treated for the purpose of maintaining acceptable IAQ.”

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Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 3. Definitions:
    - Zone Ventilation Efficiency: “the efficiency with which a system distributes outdoor air from the intake to an individual breathing zone…
      - 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.

Perfect mixed air system: Zone Air Distribution Effectiveness = 1.0

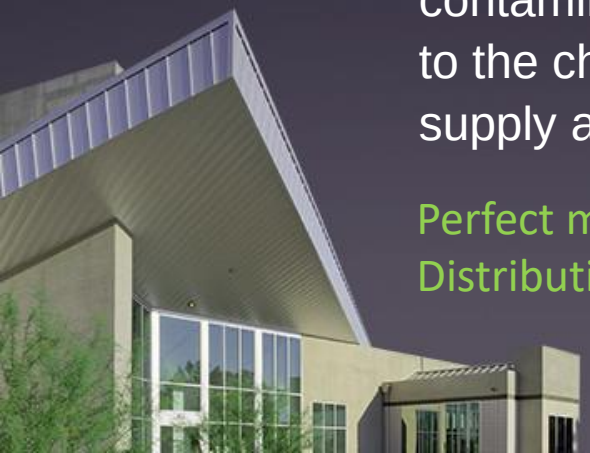


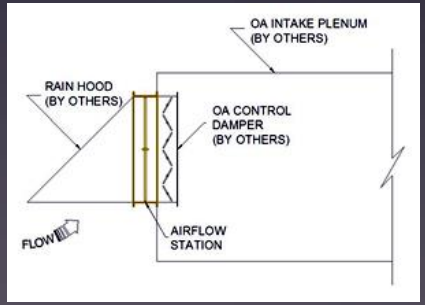
Table 6-4 Zone Air Distribution Effectiveness

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

Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 5. Systems and Equipment:
    - 5.1.1 Designing for Air Balancing
      - Ventilation air distribution systems shall be provided that allow field verification of outdoor air intake flow (V_{ot}) during operation.

Airflow Measuring Stations at AHU OSA Intake



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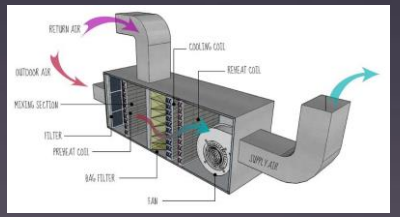
Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 5. Systems and Equipment:
    - 5.1.1 Designing for Air Balancing
      - The ventilation air distribution system for variable air volume (VAV) and multispeed constant air volume (CAV) applications shall be provided with means to adjust the system to achieve at least the minimum ventilation airflow as required by Section 6 under any load condition or dynamic reset.

Cooler Months of the Year



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Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 6. Procedures:
    - Table 6-1 Minimum Ventilation Rates in Breathing Zone

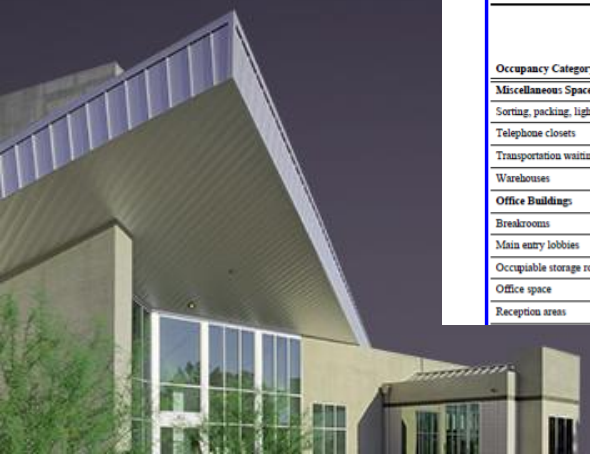

Table 6-1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

~~(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)~~

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values		
					Occupant Density		
	cfm/person	L/s-person	cfm/ft²	L/s-m²	#/1000 ft² or #/100 m²	Air Class	OS (6.2.6.1.4)
Miscellaneous Spaces (continued)							
Sorting, packing, light assembly	7.5	3.8	0.12	0.6	7	2	
Telephone closets	—	—	0.00	0.0	—	1	
Transportation waiting	7.5	3.8	0.06	0.3	100	1	✓
Warehouses	10	5	0.06	0.3	—	2	
Office Buildings							
Breakrooms	5	2.5	0.12	0.6	50	1	
Main entry lobbies	5	2.5	0.06	0.3	10	1	✓
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3	2	1	
Office space	5	2.5	0.06	0.3	5	1	✓
Reception areas	5	2.5	0.06	0.3	30	1	✓

- People Outdoor Air Rate (CFM/Person)
- Area Outdoor Air Rate
- Occupant Density
- Air Classification
  - Class 1
  - Class 2
  - Class 3
  - Class 4

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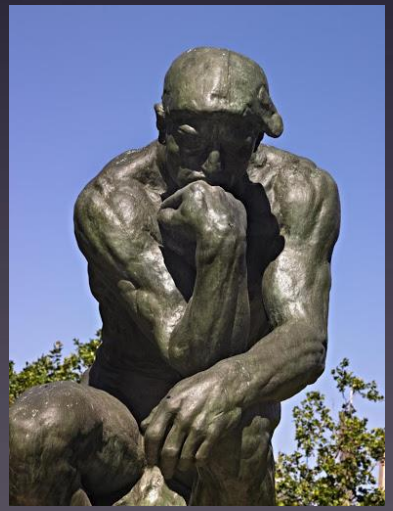
Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - 5. Systems and Equipment:
    - 5.1.1.1 Designing for Varying Loads and Operating Conditions



CHALLENGES:

- How many VAV air handlers and DX units are maintaining the minimum flow of outside air when system is at part load when building VAV boxes throttle to a minimum position?
- Is Zone Ventilation Efficiency being maintained at part load?

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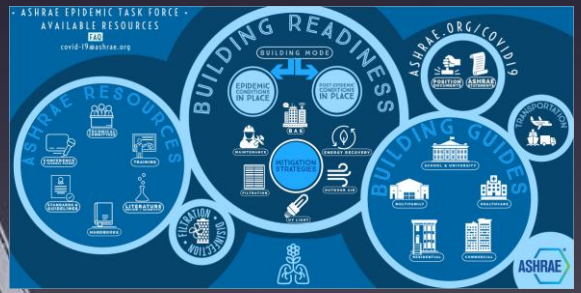
Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - Epidemic Task Force: Building Readiness
    - 5: HVAC Systems: General



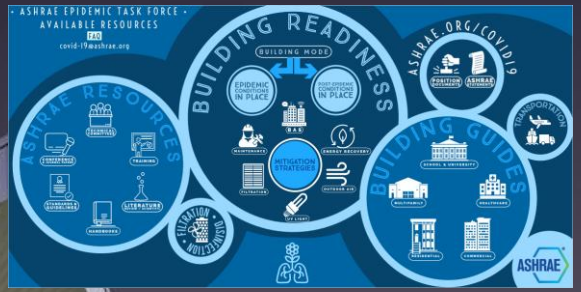
Guidance:

“Verify and commission HVAC systems to ensure at least minimum outside air are delivered to each space per ASHRAE Standards 62.1 and outdoor air dampers are properly controlled.

Are OSA/RA dampers properly controlled to modulate to the appropriate positions to supply minimum outside air to each space per ASHRAE Standards 62.1?

Indoor Air Quality (IAQ)

- ASHRAE Standard 62.1 (2019)
  - Epidemic Task Force: Building Readiness
    - 5: HVAC Systems: General



- VAV system with economizer cycle – provide additional outside air, up to 100% if it does not penalize energy.
- Disable demand control ventilation.
- If there will be a larger energy penalty, use minimum outside air per ASHRAE Standard 62.1 and provide minimum MERV-13 filters.

Indoor Air Quality (IAQ)

Advantages:

- Healthier Environment
- Reduced risk of infection
- Potential for increased energy efficiency for retrofit and new construction.

Disadvantages:

- Cost of retrofit
- Potential for higher operating cost
- Possible higher building first cost

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Questions?

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Air Patterns

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Air Patterns

ASHRAE Epidemic Task Force: 3.2 Ventilation and Air-Cleaning Strategies

- “The design and operation of HVAC systems can affect infectious aerosol transport…”
- “The following HVAC strategies have the potential to reduce the risks of infectious aerosol dissemination: air distribution patterns…”
    - (Pantelic and Tham 2013) “Ventilation with effective airflow patterns is a primary infectious disease control strategy through dilution of room air around a source and removal of infectious agents (CDC 2005).

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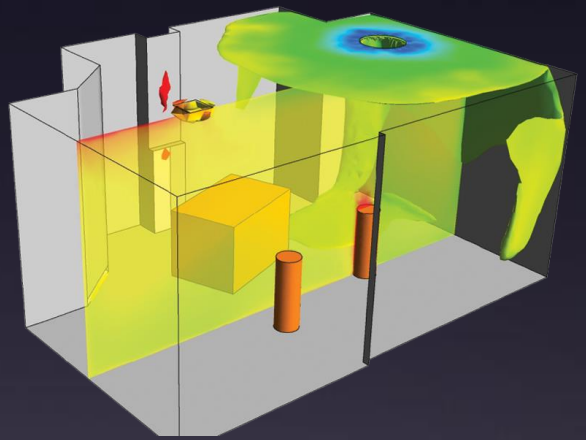
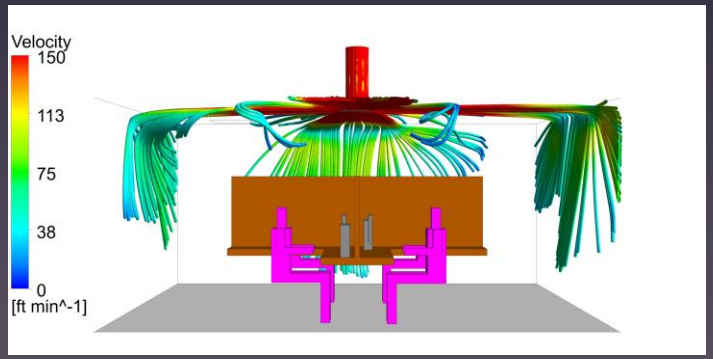
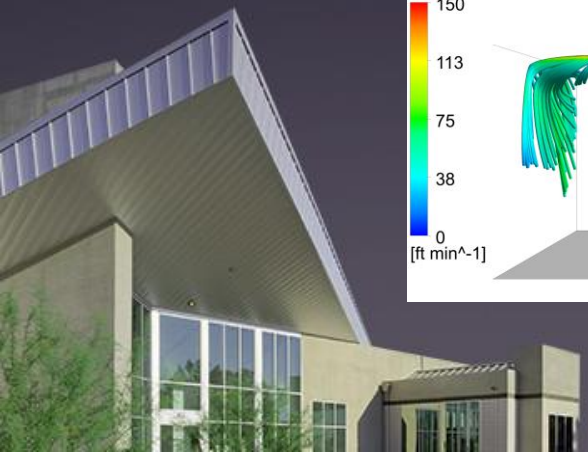
Air Patterns



Mixed Air Systems:

- Inject air at high velocity (150 FPM) to induce room air into the supply air jet to create a uniformly mixed air environment; i.e., 75F db throughout the cubic volume of space.





- Percentage of OSA in the supply air stream set by OSA dampers at OSA intake.

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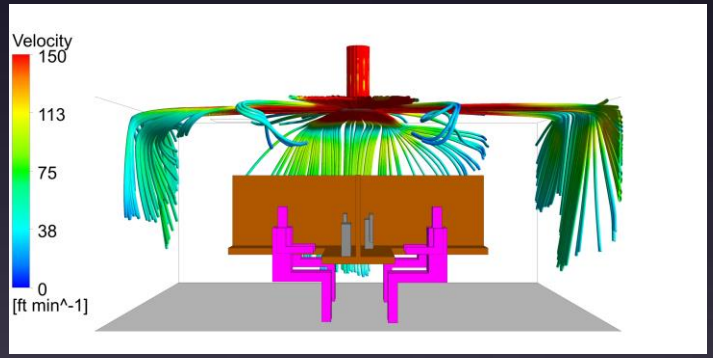
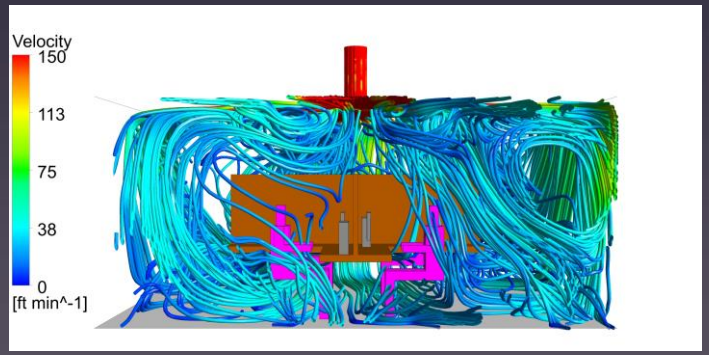
Air Patterns

Mixed Air Systems

- When zone load is satisfied, VAV box reduces airflow.
- Diffuser discharge velocity reduced
- Effective mixing in the space reduced



100% Flow



25% Flow

- What is the percentage of OSA in the supply air stream at part load?

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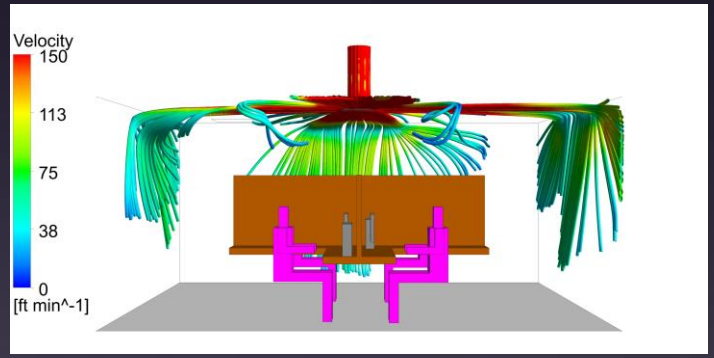
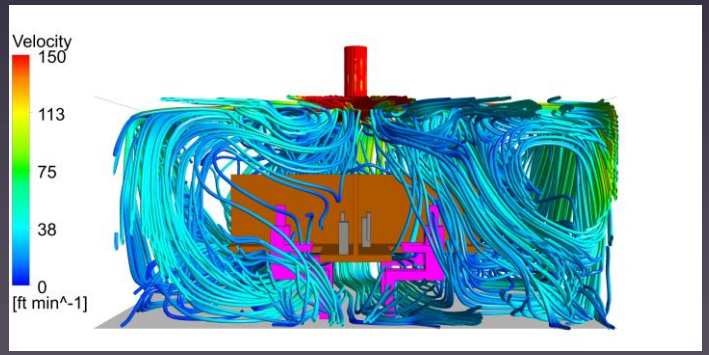
Air Patterns

Mixed Air Systems: The VAV Challenge

- When zone load is satisfied, VAV box reduces airflow.
- Diffuser discharge velocity reduced
- Effective mixing in the space reduced



100% Flow



25% Flow

- What percentage of OSA in the supply air stream at part load?

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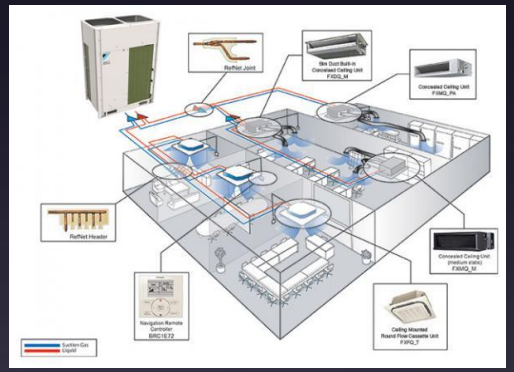
Air Patterns

Mixed Air Systems: The VRV Challenge

- Indoor Cassettes: Part Load
- Outside air duct often connected to the indoor AHU.
- Airflow rate to the space varies per thermostat demand.



- Reduced airflow
- Reduced IDU discharge velocity
- Risk of reduced OSA to space
- Variation of pathogen concentration in the space
- Less room air dilution

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Air Patterns

Mixed Air Systems: The VAV Challenge

What time of year do HVAC systems operate at less than 100% of flow

- Autumn
- Winter
- Spring

Is sufficient ventilation air delivered to the breathing zone **prescribed** by ASHRAE Standard 62.1?

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Air Patterns

Mixed Air Systems: The VAV Challenge

Season for high rates of infection:

- Increased concentrations of pathogens
- Risk of insufficient air mixing in the space
- Risk of pathogen concentration build up
- Driest time of year

- Reduced zone air change rates
- Reduced return air to AHU filtration bank
- Longer “age of air” times in zone

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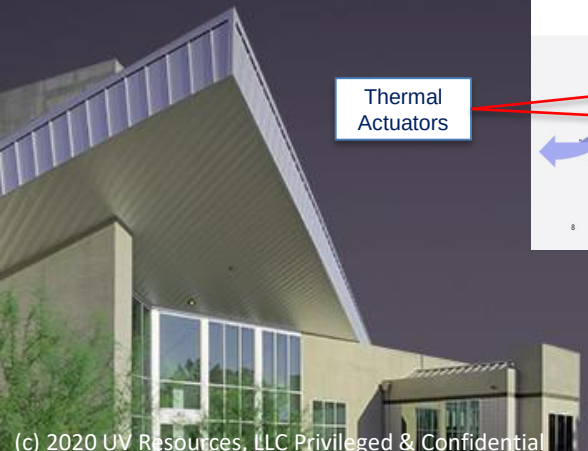
Air Patterns

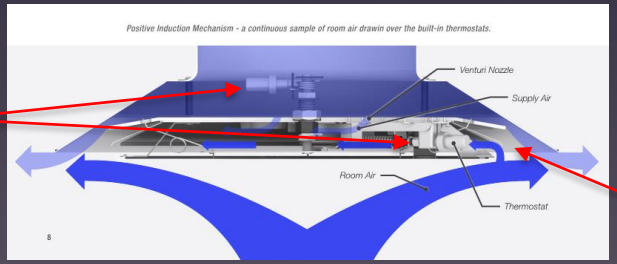
Mixed Air Systems: The VAV Challenge

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.

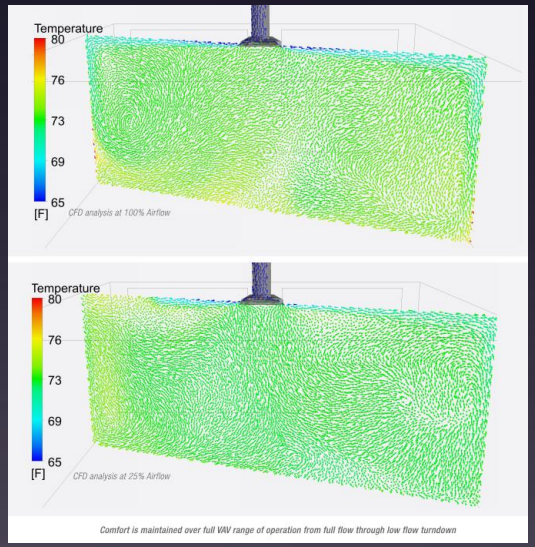


Thermal Actuators



Modulating Vanes

100% Flow



25% Flow

Mechanical or DDC Operation

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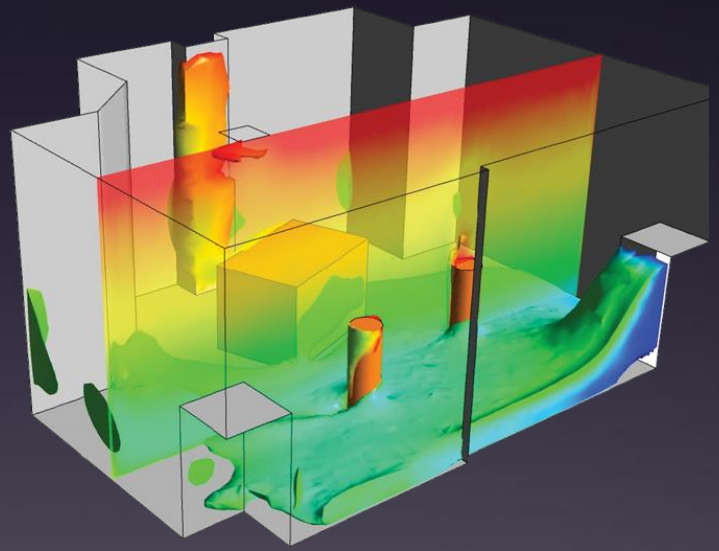
Airflow Patterns

Displacement Ventilation: The Solution?

- Thermally stratified environment
- Convection: Warm air rises/cold air falls
- Heat sources in the space create thermal plumes
- Thermal Convective Plumes drive air to upper room level to be exhausted from space.



Heat drives the air, not fan energy

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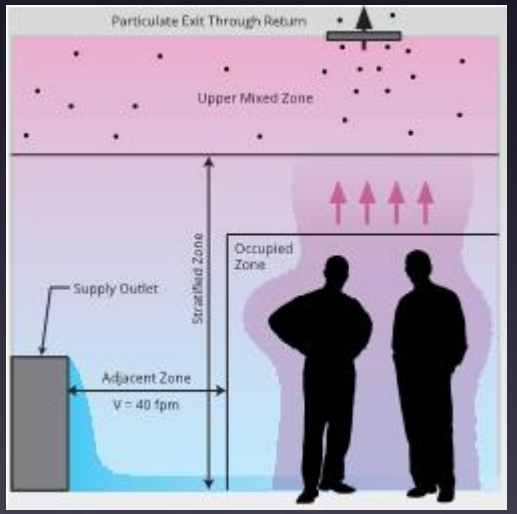
Airflow Patterns

Displacement Systems:

- 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



- Warm contaminated air rises out of the breathing zone to the upper levels of a room.

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Airflow Patterns

Displacement Ventilation: Std. 62.1-2019

- 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.

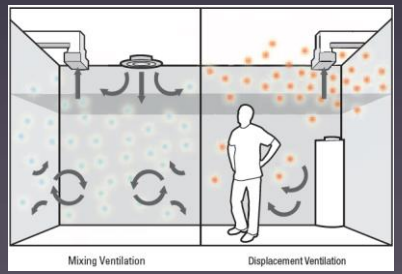

Table 6-4 Zone Air Distribution Effectiveness

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

Research: Sandia Laboratory

- Sandia Report: by Dr. Clifford Ho, PhD
  - Modeling Airborne Transmission of SARS-CoV-2 (COVID-19)
    - The current work describes computational modeling and analyses that quantify the spatial and temporal exposure and infection risks of different expiratory events (e.g., coughing/sneezing, breathing talking) as a function of physical distancing, environmental factors (e.g., airflow/ventilation), and face coverings.

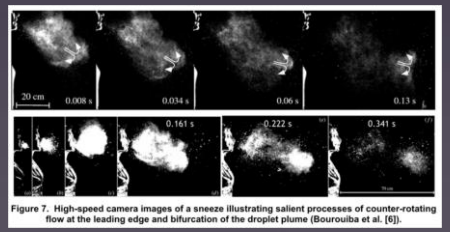

Figure 7. High-speed camera images of a sneeze illustrating salient processes of counter-rotating flow at the leading edge and bifurcation of the droplet plume (Bourouiba et al. [6]).

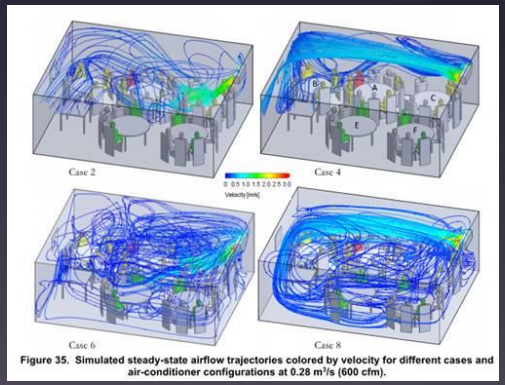

Figure 35. Simulated steady-state airflow trajectories colored by velocity for different cases and air-conditioner configurations at 0.28 m^3/s (600 cfm).

Air Patterns

Advantages:

- Low Pressure VAV:
  - High velocity air at part load conditions to maximize mixing in the space
  - Low pressure, energy efficient
- Displacement Ventilation
  - Better indoor air quality
  - Healthier building environments
  - Superior energy efficiency

Disadvantages:

- Not well known in the market
- Displacement has a higher first cost

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Questions?

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System Integration

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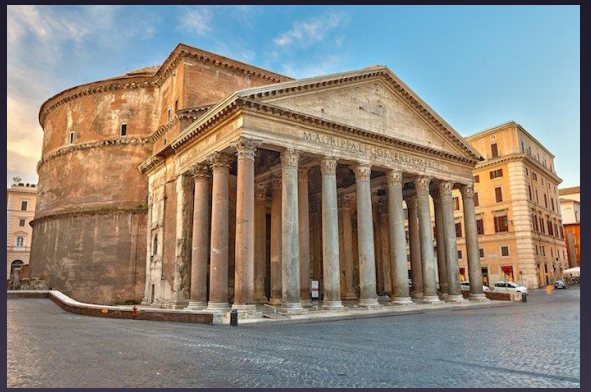
ASHRAE Epidemic Task Force

Task Force Navigation:

"All roads lead to Rome"
(Alain de Lille, 1175 A.D.)



(The Pantheon)

"All roads lead to Dilution"
(Varitec Sales Engineer)

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System Integration

Building Retrofit Applications:

ASHRAE: Epidemic Task Force

- Filtration & Disinfection: Mechanical Air Filters
  - MERV ≥ 13: Efficient at capturing airborne viruses
  - MERV 14 filters are preferred
  - High Efficiency particulate air (HEPA) filters are more efficient than MERV 16

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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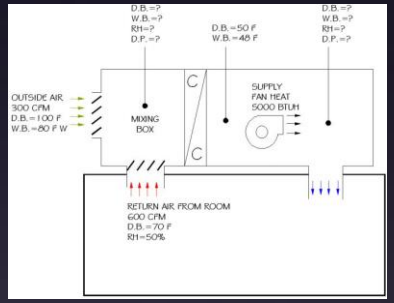
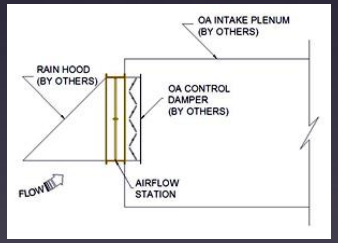
System Integration

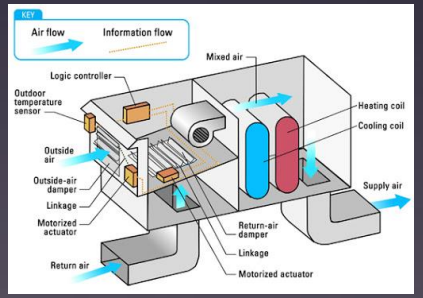
Building Retrofit Applications:

- Optimize outside air



- OSA airflow measuring for Zone Air Distribution Effectiveness for standard minimum at all loads





- Add modulating actuators to the AHU RA/OSA dampers to increase OSA at part load

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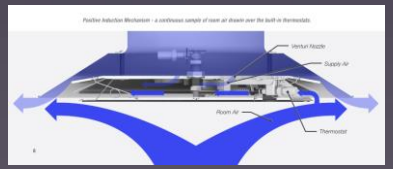
System Integration

Building Retrofit Applications:

- UV-C Light Technology
  - On-The-Fly / Coil & Surface Disinfection
    - In-Room UV-C Light

- ASHRAE Epidemic Task Force Recommendation MERV 13 filtration with UV Light

- In-Room UV Light with Low Pressure VAV Diffusers



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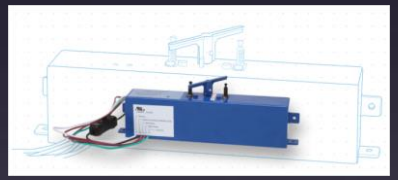
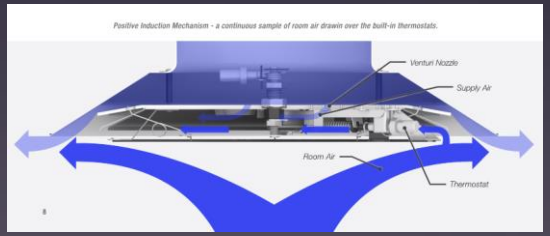
System Integration

Building Retrofit Applications:

- NPBI Ionization technology



Enhanced MERV filtration



- Ionization technology with Low Pressure VAV Diffusers

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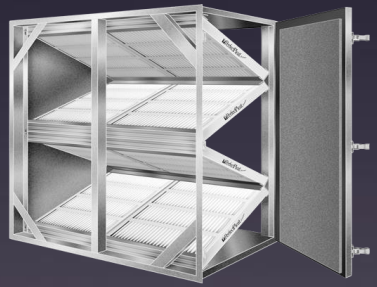
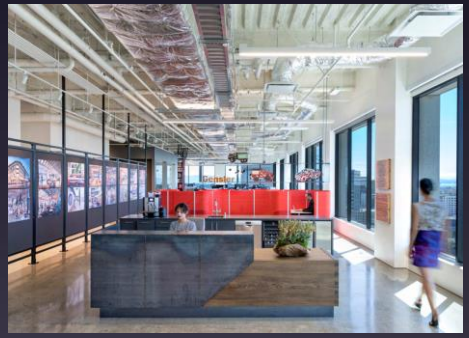
System Integration

New Construction:

- Low Pressure VAV systems to maximize mixing in the space at full and low flow



Gensler Office: Oakland, CA.



- Low Pressure VAV w/MERV 13 filtration

- Humidification maintained at 40-60%

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System Integration

New Construction:

- Displacement Ventilation Systems

- Humidification maintained at 40-60%

- NPBI Ionization

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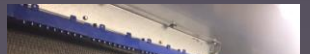
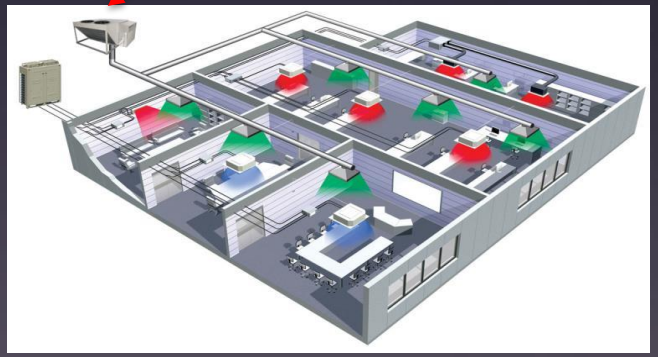


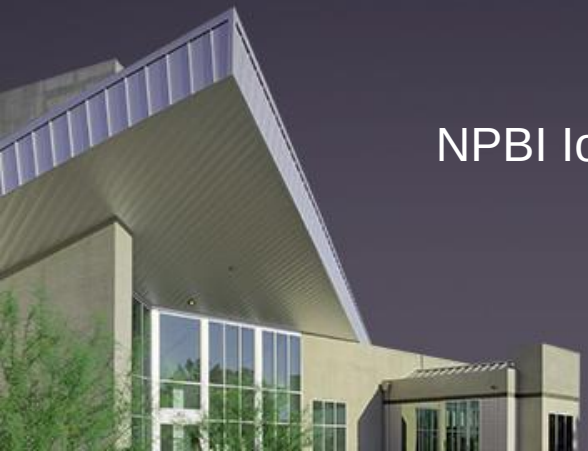
System Integration

New Construction:

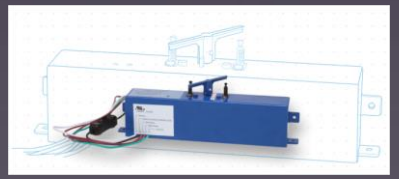
- 100% Outside Air Systems (Parallel)
  - Variable Refrigerant Systems
    - Reduced load and sizing of indoor AHUs and condensers
    - Improved VRV System Efficiency
      - EAT = Room Air Condition

100% OSA Unit





NPBI Ionization



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System Integration

New Construction:

- 100% Outside Air Systems
  - Active Chilled Beams (Constant Volume)
    - Occupied/Unoccupied
    - Design ACH for dilution effectiveness
    - Building air exhausted not returned to AHU
    - Ionization

- NPBI Ionization

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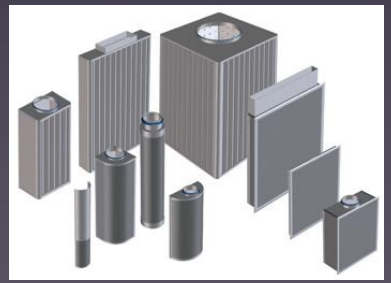
System Integration

New Construction:

- 100% Outside Air Systems
  - Passive Radiant Systems
    - Hydronic Radiant Panels
    - Displacement Ventilation for ventilation air
    - Building air exhausted not returned to AHU



Displacement Ventilation

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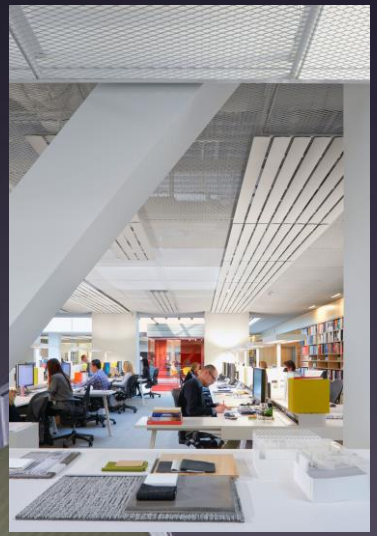
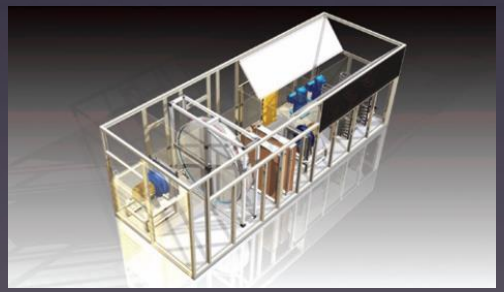
System Integration

New Construction:



- 100% Outside Air Systems
  - Passive Radiant Systems
    - Hydronic Radiant Panels
    - Displacement Ventilation for ventilation air
    - Building air exhausted not returned to AHU



DX DOAS with Passive Desiccant for Latent Control

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Integrated Design and System Concepts

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The Engineered System Solution Resource and for Healthier Built Environments!

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