Session #7:

Thermally Stratified Environments

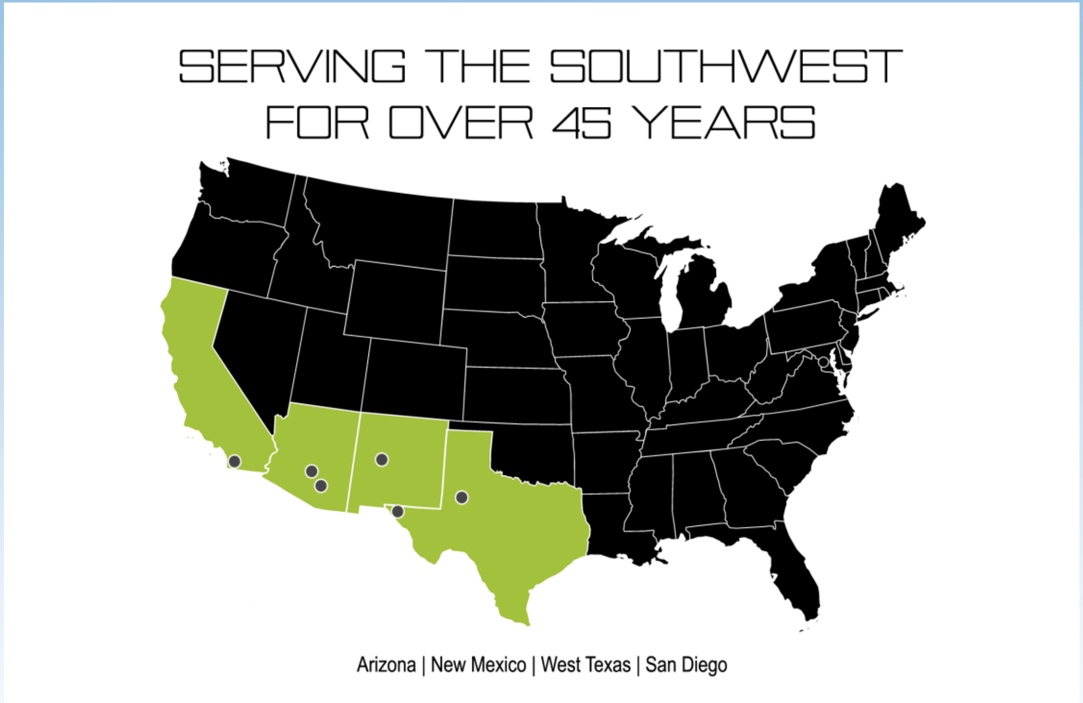
Introduction

- **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

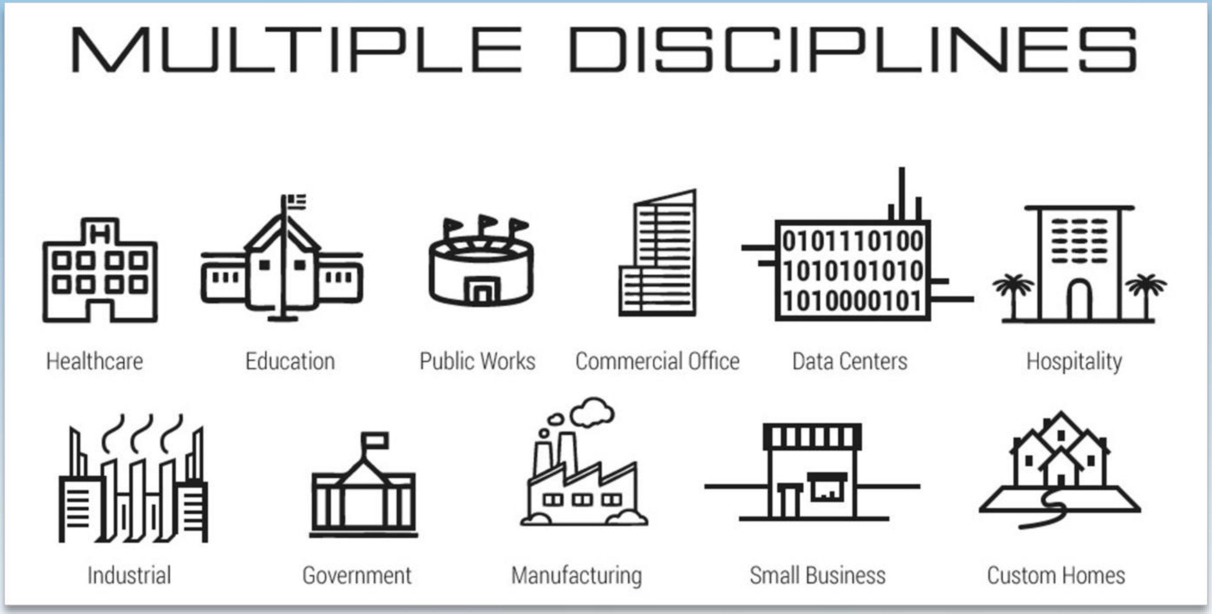
- **Industry:**
  - Norman S. Wright SW: Estimator/Sales
    - 1985 thru 1999
  - Air Specialty Products/ThermAir Systems – Outside/Engineering Sales
    - 2000 thru 2008
  - **Varitec Solutions:**
    - Senior Sales Engineer/Educator (High Performance HVAC)
    - 2016 thru present

Varitec: The HVAC System Solution

Varitec: The HVAC System Solution



Varitec: The HVAC System Solution



Varitec: The HVAC System Solution

System Solutions:

- Variable Refrigerant Systems
- 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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Varitec: The HVAC System Solution

Shaping
The Future
Of HVAC

Varitec Technical Institute

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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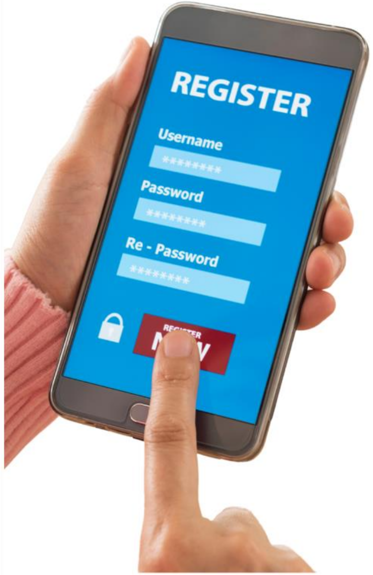
Varitec Technical Institute

2021 Educational Webinar Schedule



- ▶ Wednesday, February 10 at 11:00 am PST
  ASHRAE Epidemic Task Force – Review and Navigating
- ▶ Wednesday, February 24 at 11:00 am PST
  Physics of Pathogen Migration
- ▶ Wedensday, March 17 at 11:00 am PST
  ASHRAE 62.1 2019
- ▶ Wedensday, April 14 at 11:00 am PST
  Humidification - Technology and Application
- ▶ Wednesday, May 12 at 11:00 am PST
  UV Lights - Technology and Application
- ▶ Wednesday, June 16 at 11:00 am PST
  Needlepoint Bipolar Ionization - Technology and Application
- ▶ Wednesday, July 14 at 11:00 am PST
  Dilution and Thermal Stratification - Displacement Ventilation
- ▶ Wednesday, August 11 at 11:00 am PST
  ASHRAE 90.1 2019 and 189 2019
- ▶ Wednesday, September 8 at 11:00 am PST
  Pathogen Mitigation: HVAC System Design Concepts
- ▶ Wednesday, October 13 at 11:00 am PST
  Low-Pressure VAV Systems
- ▶ Wednesday, November 3 at 11:00 am PST
  100% OSA Systems Part 1
- ▶ Wednesday, December 8 at 11:00 am PST
  100% OSA Systems Part 2
- ▶ Wednesday, January 12, 2022 at 11 am PST
  ASHRAE 170 2017

PDH CREDITS AVAILABLE

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Thermally Stratified Environments

Presentation Resources:

References:

- Dan Int-Hout (ASHRAE Fellow)
- ASHRAE Fundamentals Handbook
- Price Engineering Handbook
- Plus One
- Elsevier
- ASHRAE Journal
- AirFixture
- Krueger

Thermally Stratified Environments

Today's Discussion:

- **Thermally Stratified Environments**
- **Three HVAC Strategies (ASHRAE)**
- **Understanding the physics of airflow in conventional mixed air systems and the nature of convection in thermally stratified environments.**

Webinar Goal:

Why Displacement Ventilation should be given every consideration for Post-Pandemic HVAC designs.

Thermally Stratified Environments

Agenda:

- Webinar Series Review
- CDC & ASHRAE: COVID-19 Transmission Update
- Physics of Room Airflow
  - Mixed-Air Systems
  - Thermally Stratified Environments
  - Wells-Riley Equation: Probability of Infection
- Displacement Ventilation
  - Cooling and Heating
  - The Terminal Device(Supply Diffuser)
  - Air Handler Configuration
- Innovative Solutions: 100% Outside Air Solutions
  - Passive Decoupled Radiant Systems

Webinar Series Review

VTI: Webinar Series Review

Session # 1

ASHRAE Epidemic Task Force: Review & Navigating

- Position Document on Infectious Aerosols
- Guide to COVID-19 Pages
- Core Recommendations for Reducing Airborne Infectious Aerosol Exposures
- Building Readiness

Session # 2

The Physics of Pathogen Migration

- The Physics of Falling Objects
- The Expiratory Event: Discharge of Pathogen
- Environmental Impacts on Pathogen Travel
- Airflow and Ventilation
- Displacement Ventilation
- Prescriptive Measures & The Future

VTI: Webinar Series Review

Session # 3

ASHRAE Standard 62.1-2019

- The Purpose of Standard 62.1
- 2019 Updates to the Standard
- The Importance of Outdoor Air
- Ventilation rates per Standard 62.1: Minimum for COVID-19 mitigation

Session # 4

Humidification

- The Nature of Water
- The Physics of Water Vapor
- Expiratory Events, Evaporation & Aerosolization
- The Risk of Infection
- Humidity an the Immune System

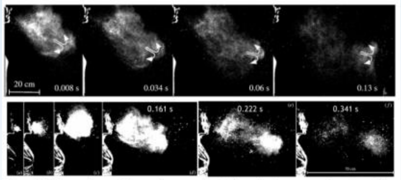


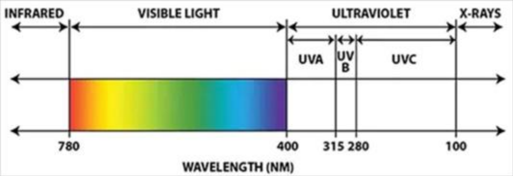
Figure 7. High-speed camera images of a sneeze illustrating salient processes of counter-rotating flow at the leading edge and bifurcation of the droplet plume (Bourouiba et al. [6]).

VTI: Webinar Series Review

Session # 5

UV-C Technology

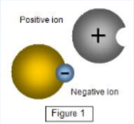
- The Nature of Light
- UV Light Generators
- Ultraviolet Germicidal Irradiation (UVGI)
- UV-C Layout: Considerations & Strategies



Session # 6

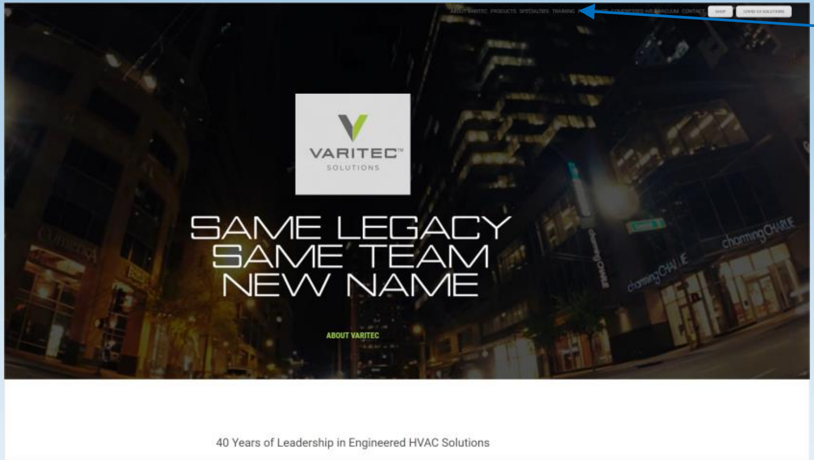
Needle Point Bi-Polar Ionization

- The latest ASHRAE guidelines and recommendations
- How NPBI technology can help make filtration & ventilation more effective
- Ozone generation considerations, concerns and regulations
- How NPBI technology works to inactivate viruses, kill pathogens…



Thermally Stratified Environment

Varitec Solutions Home Page: www.varitecsolutions.com



- Click on **TRAINING TAB**
- Click on **PAST WEBINARS**
- Click on **COURSES**
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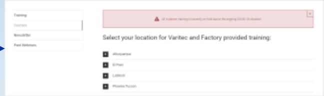
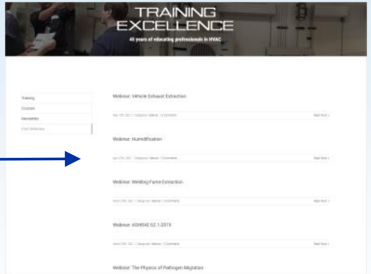


- **TRAINING EXCELLENCE:** Cascading Topic List



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CDC & ASHRAE:
COVID-19 Transmission Update

CDC & ASHRAE: COVID-19 Transmission Update

The New York Times

The Coronavirus Outbreak › | LIVE Latest Updates | Maps and Cases | Vaccine Rollout | Second Dose | Outdoor Mask Guidance

The virus is an airborne threat, the C.D.C. acknowledges.

People crowded together at a bar in El Paso, Tex., in March. The coronavirus spreads through airborne transmission, particularly indoors, the C.D.C. emphasized on Friday. Justin Hamel for The New York Times

By Roni Caryn Rabin and Emily Anthes

May 7, 2021

Federal health officials on Friday updated public guidance about how the coronavirus spreads, emphasizing that transmission occurs by inhaling very fine respiratory droplets and aerosolized particles, as well as through contact with sprayed droplets or touching contaminated hands to one's mouth, nose or eyes.

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

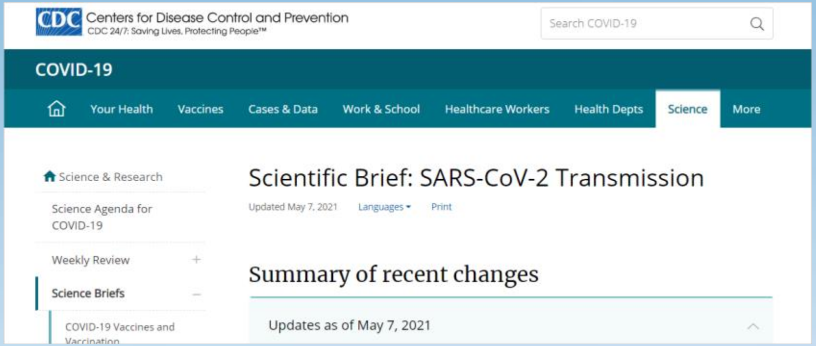
New York Times May 7th Article:
CDC Change on SARS-CoV-2 Transmission

SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory fluids carrying infectious virus. Exposure occurs in three principal ways: (1) inhalation of very fine respiratory droplets and aerosol particles, (2) deposition of respiratory droplets and particles on exposed mucous membranes in the mouth, nose, or eye by direct splashes and sprays, and (3) touching mucous membranes with hands that have been soiled either directly by virus-containing respiratory fluids or indirectly by touching surfaces with virus on them.

(Date: May 7, 2021)

CDC & ASHRAE: COVID-19 Transmission Update



May 7, 2021 Posting

- **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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CDC & ASHRAE: COVID-19 Transmission Update

May 7, 2021 Posting

- Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principle ways (not mutually exclusive):
  - **Inhalation** of air carrying very small droplets and aerosol particles that contain infectious virus.
  - **Deposition** of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e. “splashes and sprays”, such as being coughed on). Risk of transmission is greatest close to an infectious source…
  - **Touching** mucous membranes with hands soiled by exhaled respiratory fluids containing virus…

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

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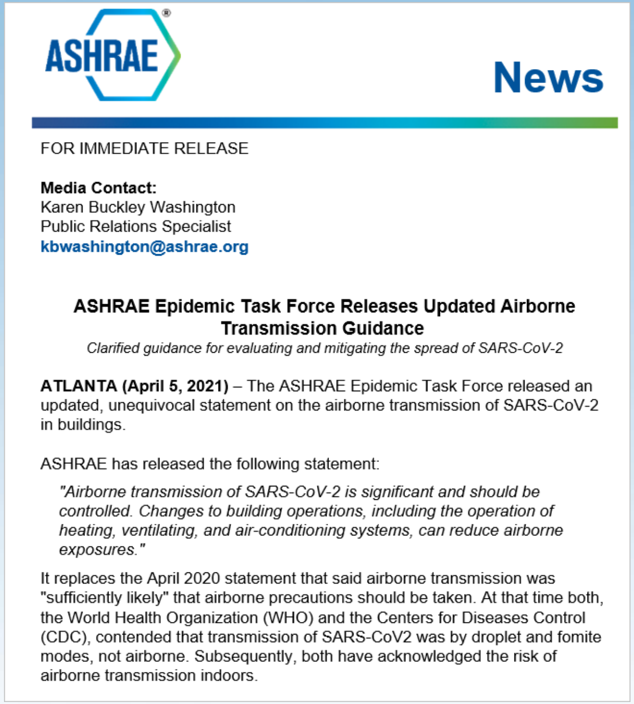
CDC & ASHRAE: COVID-19 Transmission Update

May 7, 2021 Posting

- **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 under these circumstances include:
    - **Enclosed spaces with inadequate ventilation or air handling** within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space
    - **Increased Exhalation** …infectious person is engaged in physical exertion
    - **Prolonged exposure** to these conditions, typically more than 15 minutes

CDC & ASHRAE: COVID-19 Transmission Update



ASHRAE

News

FOR IMMEDIATE RELEASE

Media Contact:
Karen Buckley Washington
Public Relations Specialist
kbwashington@ashrae.org

ASHRAE Epidemic Task Force Releases Updated Airborne Transmission Guidance

Clarified guidance for evaluating and mitigating the spread of SARS-CoV-2

ATLANTA (April 5, 2021) – The ASHRAE Epidemic Task Force released an updated, unequivocal statement on the airborne transmission of SARS-CoV-2 in buildings.

ASHRAE has released the following statement:

"Airborne transmission of SARS-CoV-2 is significant and should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures."

It replaces the April 2020 statement that said airborne transmission was "sufficiently likely" that airborne precautions should be taken. At that time both, the World Health Organization (WHO) and the Centers for Diseases Control (CDC), contended that transmission of SARS-CoV2 was by droplet and fomite modes, not airborne. Subsequently, both have acknowledged the risk of airborne transmission indoors.

ASHRAE: Epidemic Task Force Review

ASHRAE NEWS: (April 5, 2021)

Updated Airborne Transmission Guidance

“Airborne transmission of SARS-CoV-2 is significant and should be controlled.

Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

It replaces the April 2020 statement…”

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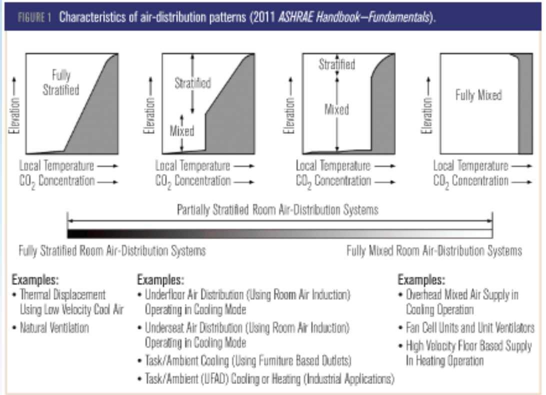
Physics of Room Airflow

Physics of Room Airflow

Air Distribution Systems: Three System Types

- **Fully Mixed: Overhead Distribution**
- **Mixed Stratified:**
  - **Semi-Turbulent Underfloor Air Systems**
- **Fully Stratified: Displacement Ventilation**



(2011 ASHRAE Handbook-Fundamentals)

Physics of Room Airflow

Mixed Air System

Physics of Room Airflow

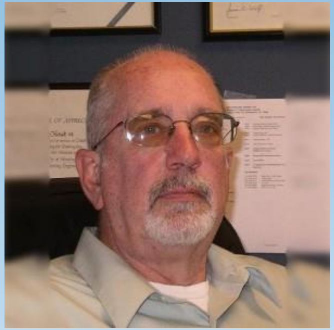
Mixed Air Systems: Purpose

Basics of Well-Mixed Room Air Distribution

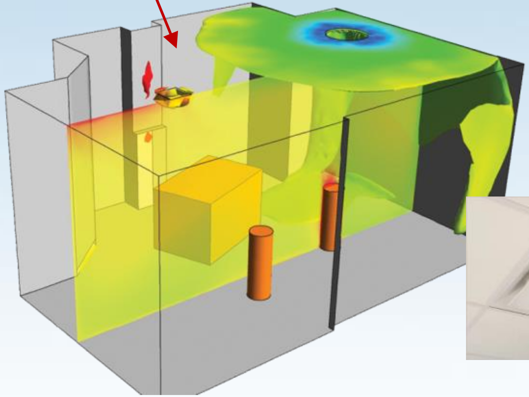
BY DAN INT-HOUT, FELLOW ASHRAE

This article is the first of three I have written for the Fundamentals at Work series. This one will cover air distribution for well-mixed systems, the most common application in commercial and institutional buildings in the U.S. It will be followed by articles on air terminals and acoustics. All three topics are interdependent, meaning that there must be an understanding of the relationship between air distribution, air delivery rates, and acoustics to properly design an HVAC system that will provide an acceptable indoor thermal environment for occupants.

(ASHRAE: Fundamentals @ Work: 2015)



(Dan Int-Hout)



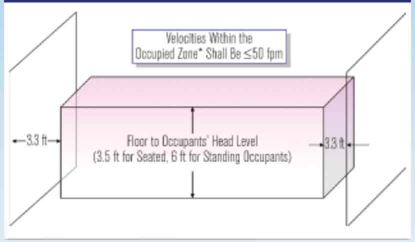
- **Thermal Comfort & Dehumidification**
- Create a **uniform temperature** throughout the cubic volume of space

Physics of Room Airflow

Mixed Air Systems: Objective

- **Rules for Fully Mixed Air Systems:**
  - “The first basic “rule” is that space **temperatures** in well-mixed spaces **should be uniform**, within a couple degrees, at all points within a defined occupied zone.”
  - “Temperatures also should remain the same throughout the day and the room must be relatively free from objectionable air currents …” (Dan Int-Hout)

FIGURE 2 Thermal comfort zone in a room per ASHRAE Standard 55-2013.



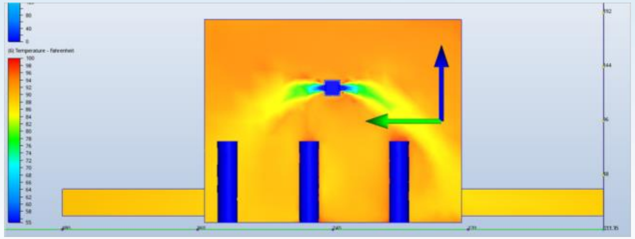
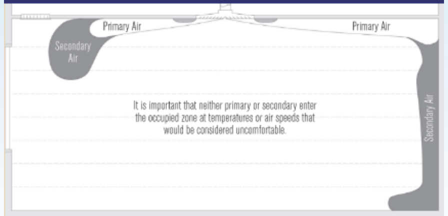


FIGURE 3 Primary and secondary airstreams.



Physics of Room Airflow

Supply Air: Design Condition @ Peak Flow

- Supply Air: Leaving Air Temperature (LAT):
  - **~55F DB**
- Supply Air Diffuser: Discharge Air Velocity
  - **~150 FPM (Peak Load)**
- Ceiling Diffusers or High In-Wall Registers
- Room air induced into the supply air stream

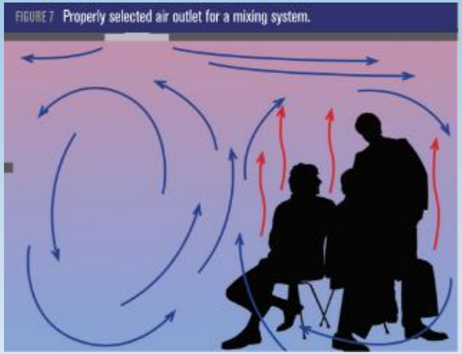
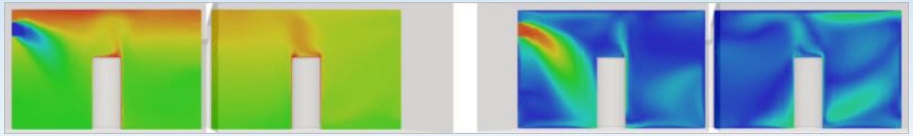


FIGURE 7 Properly selected air outlet for a mixing system.



(Temperature Profile) (Velocity Profile)

Convection & Room Air Distribution

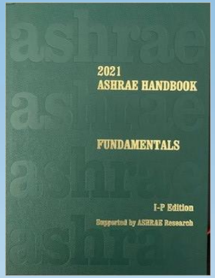
- Denser **cold air** tends to fall
- Less dense **hot air** tends to rise

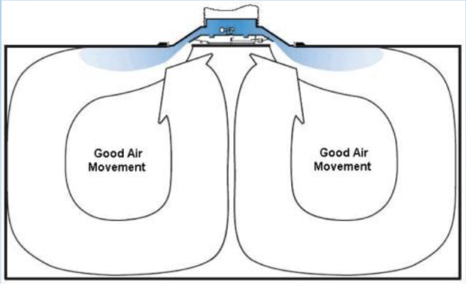
NOTE: High Velocity Discharge Required for Mixing

Physics of Room Airflow

Physics of Airflow: Velocity & Pressure

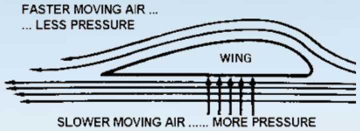
- High Pressure Moves to Low Pressure
- To Maximize Room Air Induction and Mixing





Coanda Effect:

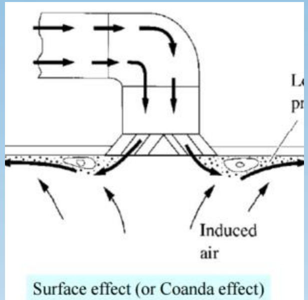
"Effect of a moving jet attaching to a parallel surface because of **negative pressure** developing between the jet and the surface."
(ASHRAE Handbook 2021: Fundamentals)



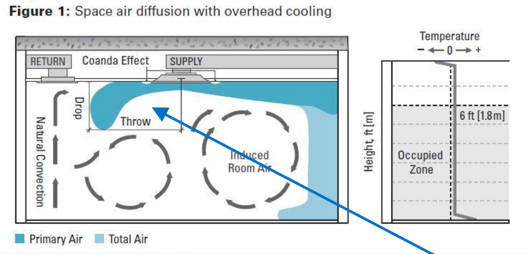
- **High Velocity-Low Pressure** air draws high pressure room air into supply air jet
- **Air Mixing Occurs. Higher Velocity = Higher Pressure Differential = Greater Mixing**
- **Air Mixing Reduced. Lower Velocity = Lower Pressure Differential = Less Mixing**
  - What is needed to create high velocity air? **FAN ENERGY**

Physics of Room Airflow

Airflow: Supply Air Discharge Profile



- Supply air jet moves across a ceiling **inducing room air into the jet** resulting in:
  - **Temperature differential: Reduced** between room and supply air.
  - **Volumetric flow** rate of moving stream **increases,** thereby increasing its **MASS**



- **Air jet velocity slows** as momentum is conserved
- Jet's ability to entrain more air decreases, **Coanda effect reduced**
- **Cooler higher density air falls** to the floor
- **Pressure Differential Reduced: Air falls**

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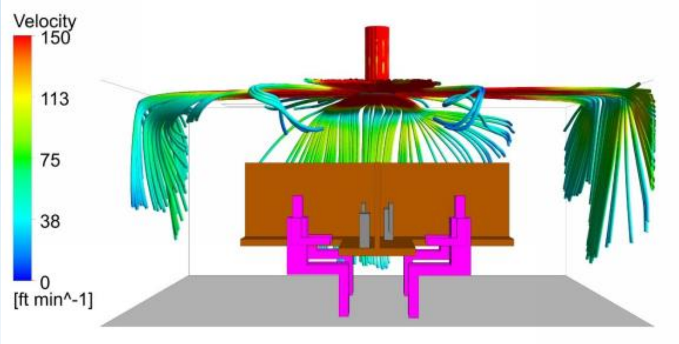
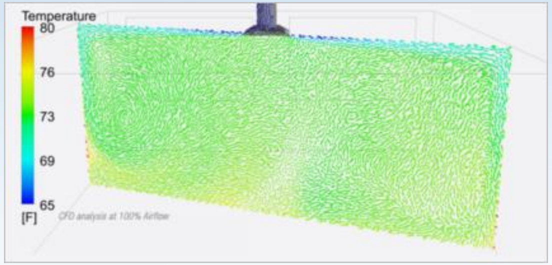
Physics of Room Airflow

Physics of Airflow: Peak Load

- Maximum airflow at the diffuser
- Diffuser velocity at design maximum



- **Uniform Mixing in the Cubic Volume of Space**
- **Uniform Temperature Profile**
- **Uniform Distribution of Contaminants**



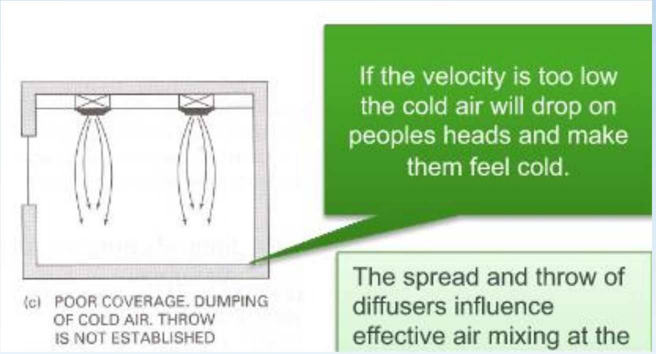
- **Discharge velocity to be maintained** for thorough mixing to occur

Physics of Room Airflow

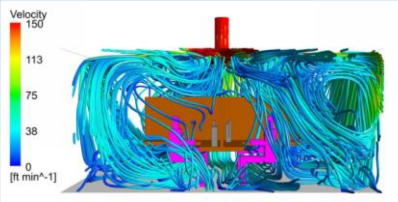
Airflow: Part Load Conditions

VAV System Thermal Comfort Complaints:

- **Lower Room Load:** Less supply air at 55F required to satisfy thermostat
- Thermostat calls for less air; **VAV boxes modulate to minimum** position**.**



Dumping



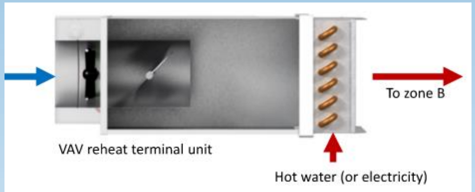
- Lower volume of supply air = **lower diffuser discharge velocity**
- Cold air **"negative buoyancy"** (cold air falls) exceeds supply air jet and ambient pressure differential

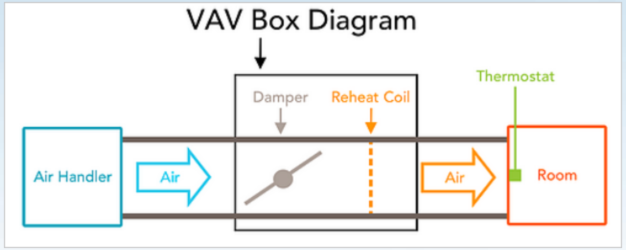
Physics of Room Airflow

Airflow: Part Load Conditions

VAV System Solution for Mixing? Constant Airflow

- **Reheat** conditioned supply air to higher temperature
- Occupied Hours:
  - **Maintain air volume** and diffuser air discharge velocity by increasing supply air temperature





- **Challenge:**
  - **INEFFICIENT**
  - **VERY EXPENSIVE**

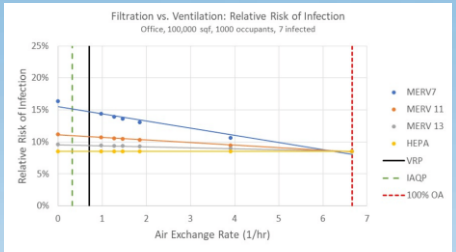
Physics of Room Airflow

Airflow and Room Load:
The Design Challenge:

- Diffuser peak discharge velocity occurs usually at **Summer Peak Load Conditions.** Greater air mixing occurs.
- Lower volume of air at non-peak conditions (VAV Systems) :
    - **Fall, Winter and Early Spring**
- Otherwise known as the **cold and flu season**

- Colder days: Building zones go into **heating mode**
- **Discharge air temperature = 85F to 95F**
- Discharge air velocity reduced by 50% or more
- **"Positive buoyancy"** of discharge air. (warmer air tends to remain at room upper levels)
- **Space air mixing is non-uniform**

Physics of Room Airflow



Airflow and Risk of Pathogenic Infection

- **Wells-Riley Equation: Risk of Infection**

$$P = 1 - e^{\frac{-Ipqt}{Q}}$$

P = *Probability of infection*

I = *Number of infector individuals in the space*

p = *Average breathing rate of individuals in the space*

q = *Quanta generation rate*

t = *Exposure time*

Q = *Air flow rate from HVAC system*

- **Derived in 1978 to model measles outbreaks** in schools.
- **"Provides a simple and quick assessment of the infection risk".** **(Lowry, AJ (KW Engineering))**

Probability of Infection

- **Quanta**: The minimum infectious viral load
- **Quantum:** Dose of airborne droplet nuclei required to cause infection in 63% of susceptible persons

Physics of Room Airflow

Airflow and Risk of Pathogenic Infection:

- **ASHRAE Journal May 2021 (Part 1)**

ASHRAE®

TECHNICAL FEATURE

COVID-19

Minimizing Transmission In High Occupant Density Settings, Part 1

BY DAVID ROTHAMER, PH.D.; SCOTT SANDERS, PH.D.; DOUGLAS REINDL, PH.D., P.E., FELLOW ASHRAE; TIMOTHY BERTRAM, PH.D.

(Rothamer, Sanders, Reindl, Bertram)

Based on a well mixed air environment

- Introduces a "…**modified Wells-Riley model** for predicting the conditional probability of infection within indoor environments…"

- "…Reported here (*within the article)* is a summary of field experiments used to determine whether the assumption inherent in the Wells-Riley model, that **the indoor space is well-mixed**, is appropriate."

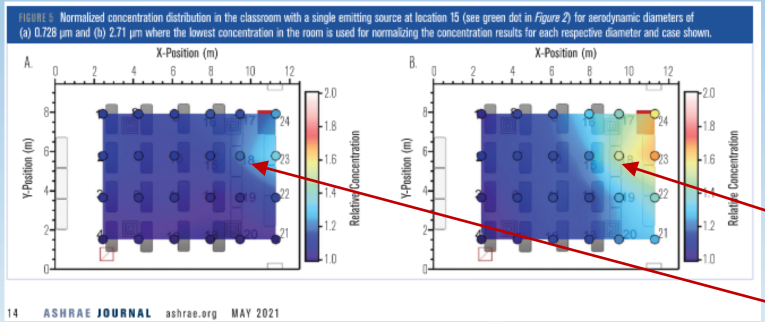
Physics of Room Airflow

COVID-19

Minimizing Transmission In High Occupant Density Settings, Part 1

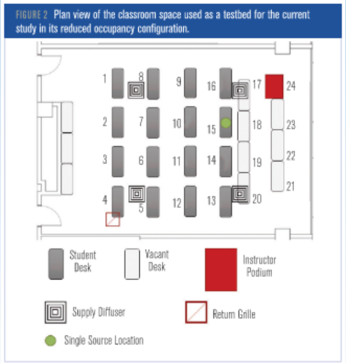
Airflow and Risk of Pathogenic Infection:

- **ASHRAE Journal May 2021**



Infected host

- Field experiments were conducted using…(NaCl) in an aerosol size range consistent with SARS-CoV-2 in two diameters; 0.728 microns and 2.71 microns



Conclusion:

- Better distribution of **0.728 micron** particles
- **2.78 micron** particles settled out more rapidly
- Application of **the modified Wells-Riley equation holds better for particles of the 0.728 micron size**

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Physics of Room Airflow

Airflow and Risk of Pathogenic Infection

- **Wells-Riley Equation: Risk of Infection**
- **ASHRAE Journal June 2021 (Part 2)**

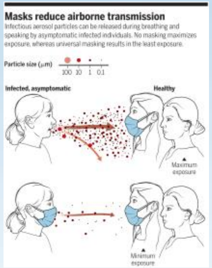
Part 2

Minimizing COVID-19 Transmission in High Occupant Density Settings

BY DAVID ROTHAMER, PH.D.; SCOTT SANDERS, PH.D.; DOUGLAS REINDL, PH.D., P.E., FELLOW ASHRAE; TIMOTHY BERTRAM, PH.D.

(Rothamer, Sanders, Reindl, Bertram)

Testing of various mask filtration media for a classroom



"…At a mask effective filtration efficiency of 0.5 (50%), the conditional infection probability is reduced by a factor of 4 relative to the no-mask baseline…all occupants wearing masks with an effective filtration efficiency of of 0.9 (90%), the conditional infection probability is reduced by a factor of 100 relative to the no-mask baseline."

Classroom Airflow Rates Air Changes per Hour (ach):

- "**Increasing room airflow** from 1.34 ach to 3 ach **reduces infection probability by a factor of 2x.**

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Physics of Room Airflow

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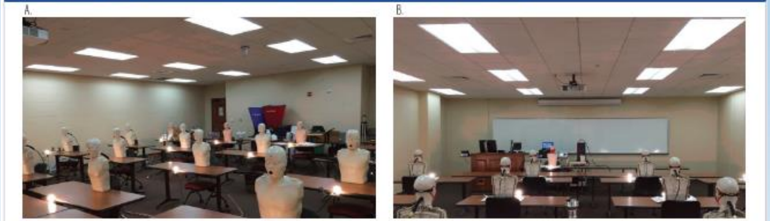
FIGURE 3 Classroom space set with CPR manikins (a) from the front looking back and (b) from the back looking forward.



(Rothamer, Sanders, Reindl, Bertram)

Conclusions and Recommendations:

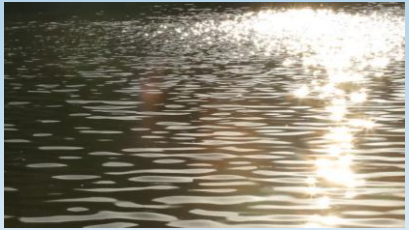
- "…the reduction in infection probability achieved with occupants wearing masks having a modest effective filtration efficiency of 0.55 (55%)…vs. the no-mask baseline is a factor of 4x.
- "Increasing room airflow from 1.34 ach to 3 ach reduces infection probability by a factor of 2x.
- **Both measures together yield a reduction in infection probability of a factor of ~8x.**

Thermally Stratified Environments

Thermally Stratified Environment

Thermal Stratification: What is it?

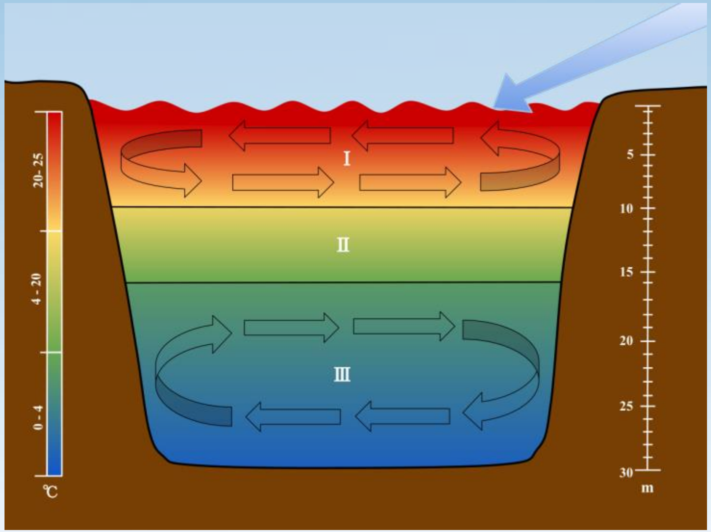
Definition: A temperature differential throughout a continuous body



Body of water:

- Surface temperature: ~ 74F
- Lower water levels: ~ 40F

Radiant Lake Effect

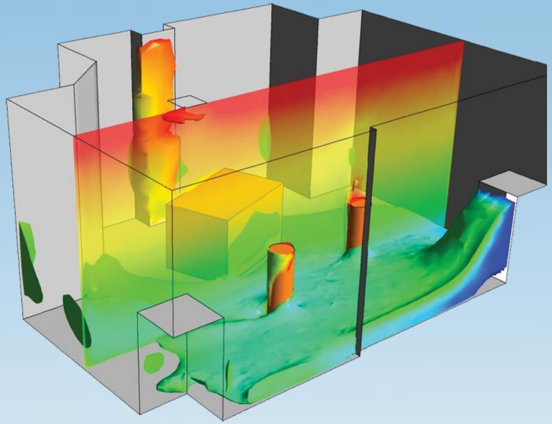


Water is thermally stratified

Thermally Stratified Environment

Thermally Stratified Building Space:

- Room Temperature Set Point: 75F
- Room Supply Air Temperature: 65F



- Stratified: Non-uniform space temperature
- Room thermal profile
  - Floor: **~ 70F**
  - Thermostat: **~75F (set point)**
  - Ceiling: **~78F to 82F (9ft AFF)**

"**The system utilizes buoyancy forces in the room**, generated by heat sources such as people, lighting, computers…"

Thermally Stratified Environment

Thermal Stratification & Air Movement

- Displaces occupied zone air **via convection** to the upper levels of a room via thermal plumes from heat sources

Thermal Plumes:

- Create temperature stratification
- Heat, not fan energy, moves air in the space
- Contaminants carried to upper levels of a room
- Improved IAQ at the breathing zone

Thermally Stratified Environment

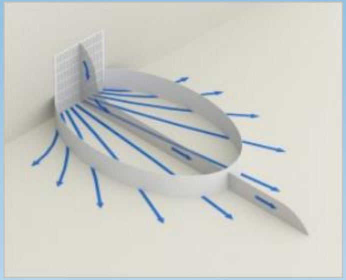
Thermal Stratification & Air Movement

Mixed Air

Displaced Air

Indoor Air Quality?

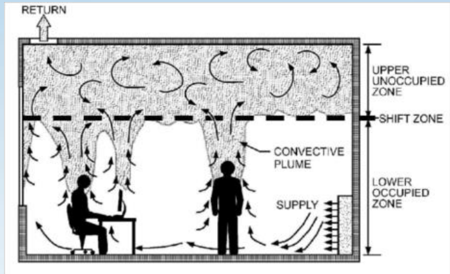
Thermally Stratified Environment



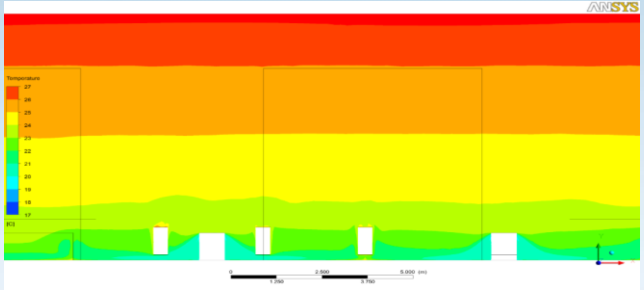
Thermal Stratification & Air Movement

Office or Classroom with Sedentary Occupants;

- **Diffuser Discharge Velocity**
  - Full Load: Diffuser Discharge Air velocity = ~ 40 FPM
  - Part Load Minimum: Discharge Air Velocity = ~20 FPM



Thermal displacement ventilation system characteristics [24].



- **Full or Part Load:** if surface temperature differential is maintained a constant flow of air rises to the upper levels of the conditioned space.

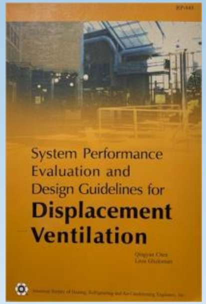
Displacement Ventilation

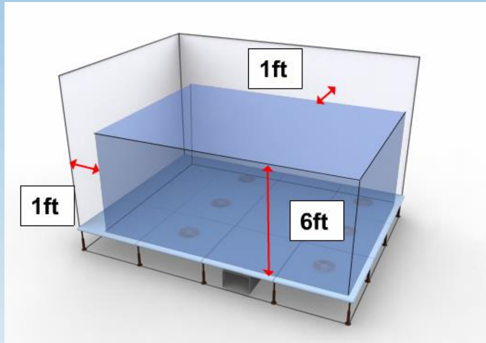
Thermally Stratified Environment

Displacement Ventilation (DV): Stratified Room Condition

ASHRAE Standard 55: Occupied Zone

- Occupied Zone:
  - 6 foot AFF, 1 foot from walls
- Upper level sensible load reduced in space





Banner Health Maricopa Clinic

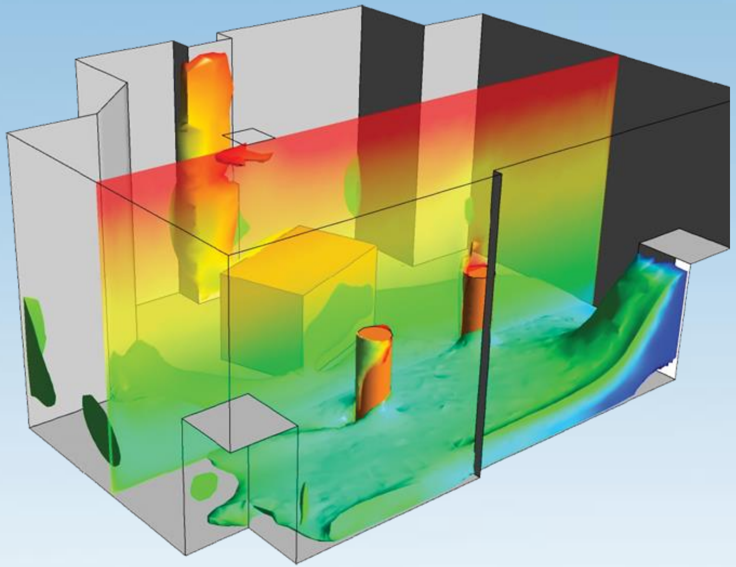
Designed at 0.8 CFM/SQFT of airflow

- **Supply 65F in lieu of 55F air:**
- **Design airflow often reduced**
- **Maricopa County: Economizer Hours Doubled (~34% annualized hours)**

Thermally Stratified Environment

Displacement Systems: Airflow

- Supply air at low velocity: **~40 FPM**
- Supply air temperature: **62-68°F**
- Upper level room air temp: **80-85°F**
- High level return/exhaust grilles



Room Temperature Profile:

- Floor: **70F**
- Thermostat at 5 feet: **~75F**
- Ceiling 8-9 feet AFF: **~80-85F**

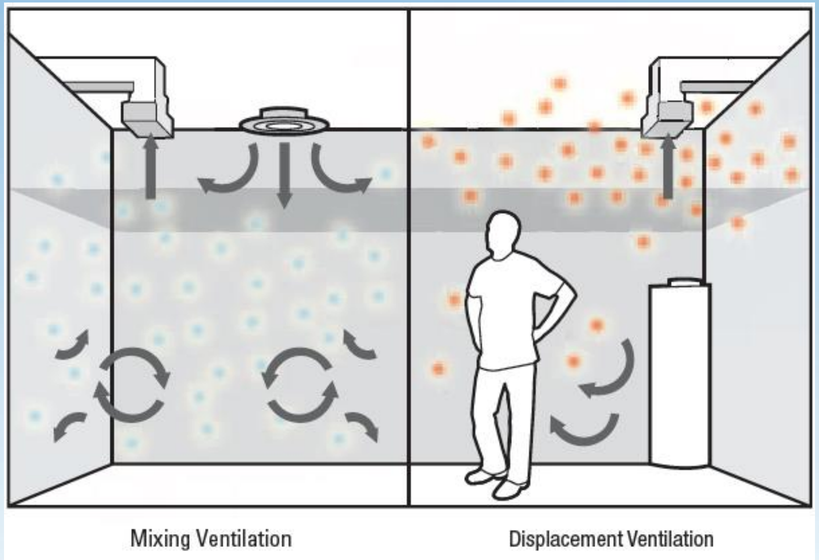
- **Thermal Comfort Temperature Range (Foot to Head):**
  - Seated occupants – 3.5 deg F
  - Standing occupants – 5 deg F

Thermally Stratified Environment

Displacement Ventilation (DV): ASHRAE Standard 62.1

- Superior Air Quality: 1.2 VE
- More efficient contaminant removal
- High Ventilation Effectiveness
- Outdoor air can be reduced
  - Local code permitting

Air Supply Method	VE (ASHRAE 62.1)
Mixing	1.0
Displacement	1.2

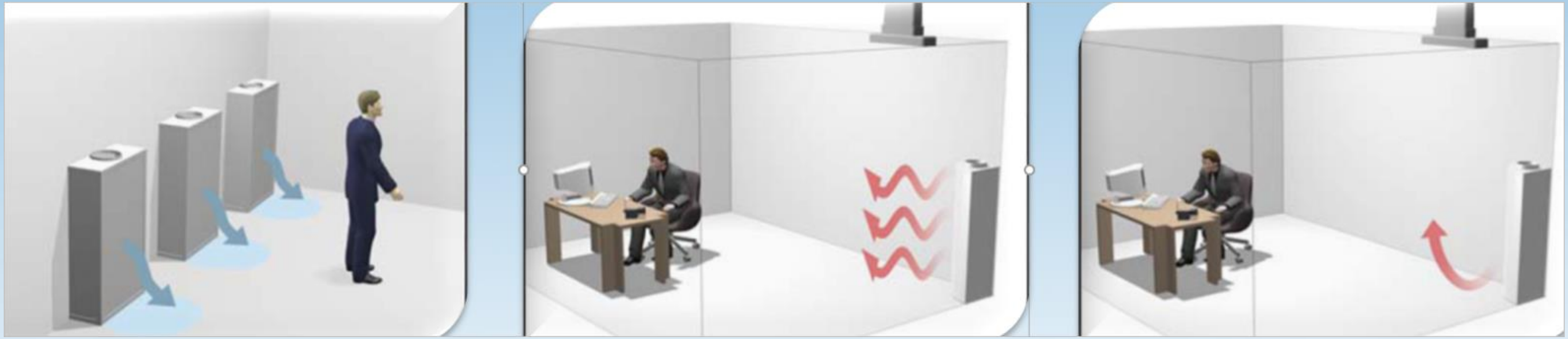


ASHRAE

Displacement Ventilation: Heating

Displacement Ventilation: Heating Mode

2-10F Degrees | 0-5F Degrees | 5 °F+ Heating

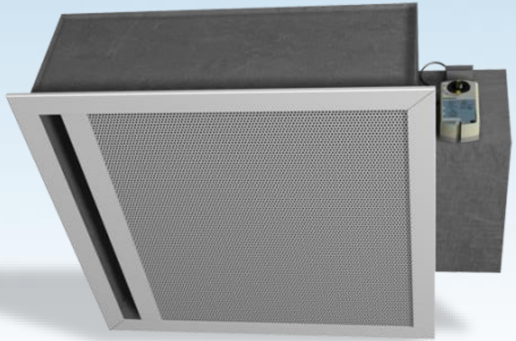


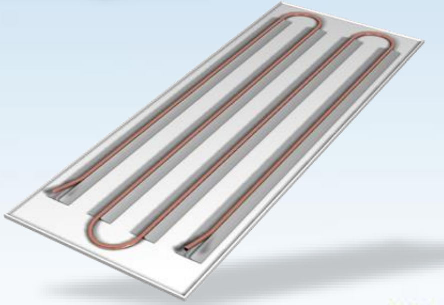
Negative Buoyancy | Zero Buoyancy | Positive Buoyancy

Displacement Ventilation: Heating Mode

Displacement: Heating Solutions

- Perimeter Radiation: Colder Climates
- Diffusers with Heating Discharge Design
- Radiant Ceiling Panels: Hydronic or Electric
- Fan Coil Units: Perimeter zones





Displacement Ventilation: Heating Mode

Baseboard Radiation:

- Hydronic
- Electric

Colder Climates

Displacement Ventilation: Heating Mode

Radiant Panels & Sails:

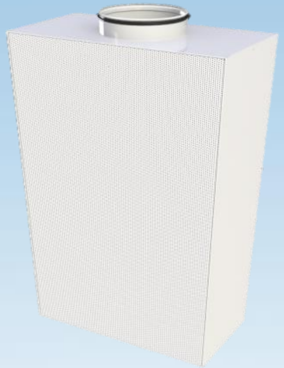
- Hydronic
- Electric

Twa

Displacement Ventilation: Product Portfolio

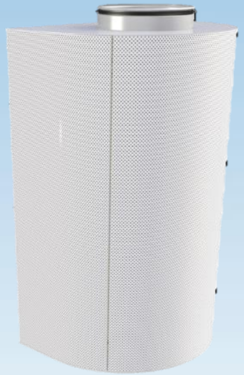
Displacement Ventilation: Product Portfolio

Low In-Wall Displacement Diffusers



Rectangular

Circular



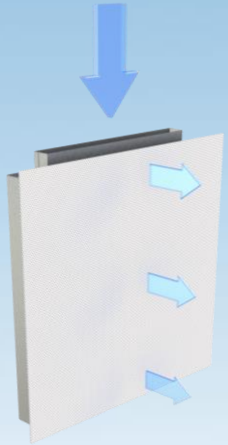
Semi-Circle

Corner

In-Wall

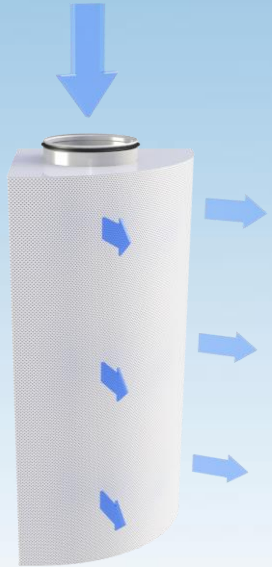
Displacement Ventilation: Product Portfolio

Rectangular in Wall Diffusers



Recessed in Walls

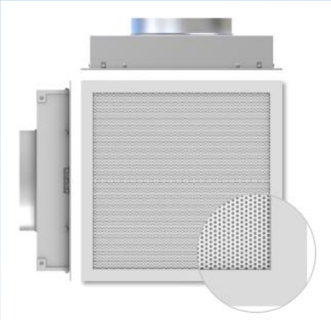
Corner Semi-Circular Diffusers



Displacement Ventilation: Product Portfolio

Ceiling Displacement Diffusers

- Lay-In Ceiling Applications



Per ASHRAE 62.1-201:

- Does **not qualify** for 1.2 ventilation effectiveness

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)

Displacement Ventilation: Product Portfolio

Semi-Circular 180 degree diffusers:

- Large airflow capacity

Displacement Ventilation: Product Portfolio

Underfloor Displacement Air Systems: Fully Stratified

Low Velocity Discharge Air @ 65F

E3 UNDERFLOOR PRODUCTS

FDD | Round Diffuser, Displacement Air Pattern

FDD

Introduction: FDD

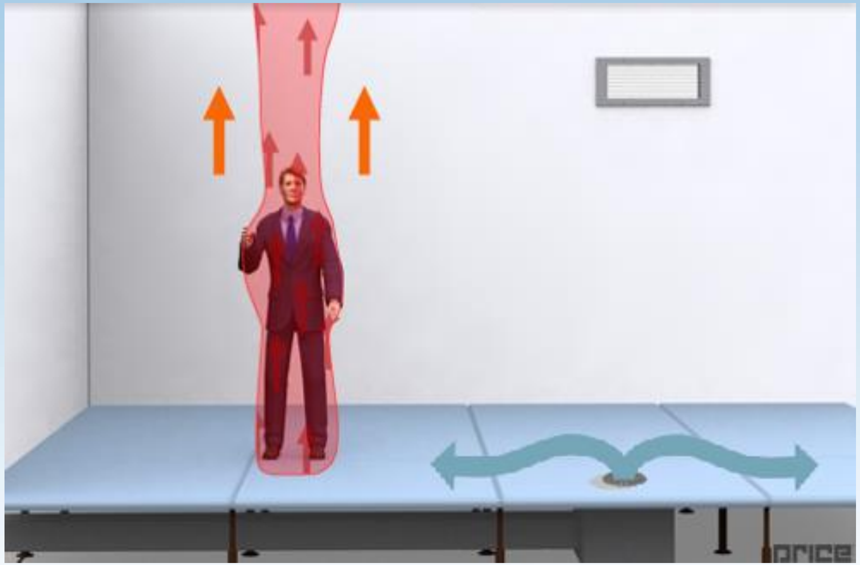
Krueger's FDD round displacement diffusers are designed to seamlessly integrate into any underfloor installation and can supplement a displacement ventilation system. The FDD provides high flow capabilities that exceed the competition. The units are made of a durable and long lasting cast aluminum construction. The FDD is available in a variety of sizes and plenum options. The plenums are pre-painted flat black to conceal them from view through the diffuser.

MODEL

FDD - Cast Aluminum Round Diffuser for Underfloor with Displacement Air Pattern

FEATURES

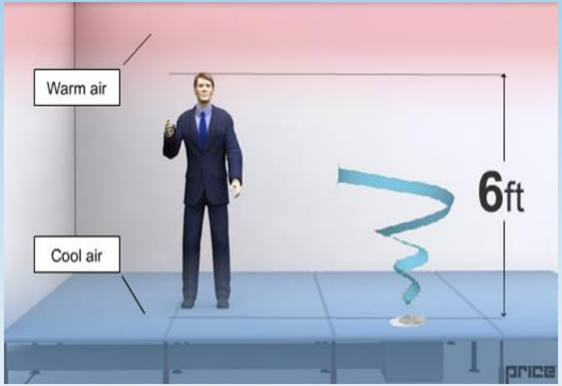
- Available in a 4", 6", 8" or 10" round nominal size.
- Ships completely assembled and is easily installed.
- 180° displacement air pattern on 4" and 6".
- 360° displacement air pattern on 8" and 10".
- Durable cast aluminum construction to withstand any application.
- Features a 1250 lbs. load rating.
- Manual airflow adjustment.
- Conforms to NFPA 90A fire requirements.
- Provided with optional factory painted flat black steel plenum on sizes 8" and 10".
- Provides silent operation less than 17NC at 100% capacity.
- When ordered alone, works in 6" raised floors. With plenum option, compatible with 8" raised floors.



Displacement Ventilation: Product Portfolio

Underfloor Displacement Air Systems: Mixed – Partially Stratified

- Semi-Turbulent Discharge @ 65F Supply Air
- Occupied Zone is a Semi-Mixed Air Environment
- Fewer Diffusers required in a space



(Semi-Turbulent Discharge)

ASHRAE Standard 62.1-2019

- Assigns 1.2 ventilation effectiveness for UFAD air systems
- 20% less outside air required

VARITEC CONTROLS & SERVICE SOLUTIONS

riptide

NSW CONTROLS & SERVICE SOLUTIONS

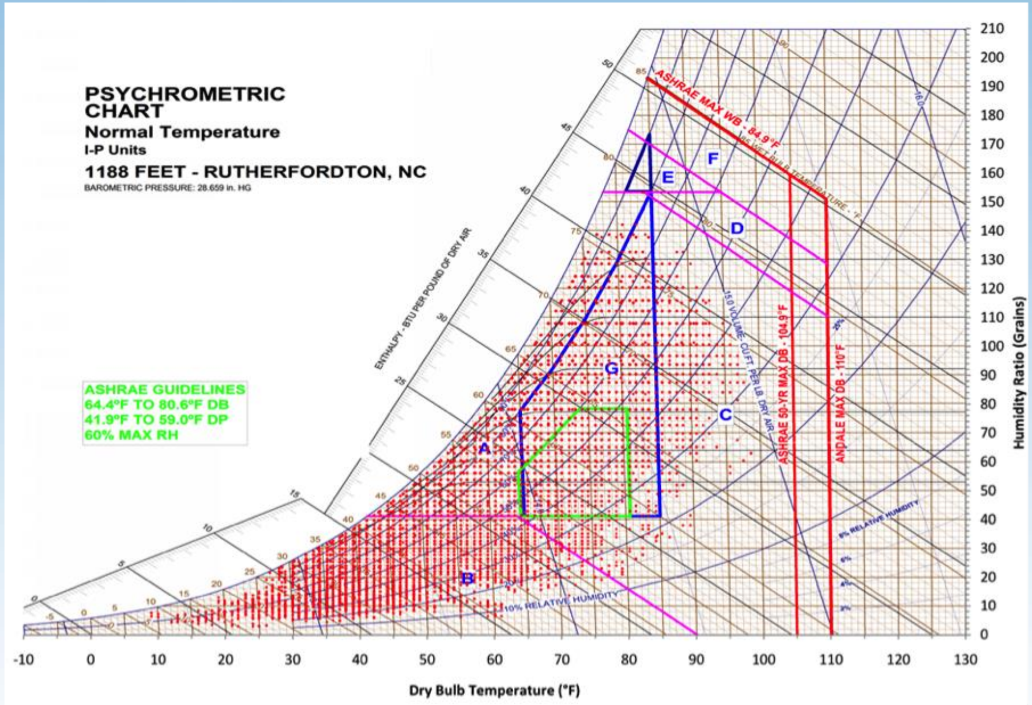
Air Handler Configurations

Air Handler Configurations

Mixed Air DV Systems

Dehumidification?

- What is dew point?
- How do you dehumidify 65F supply air?

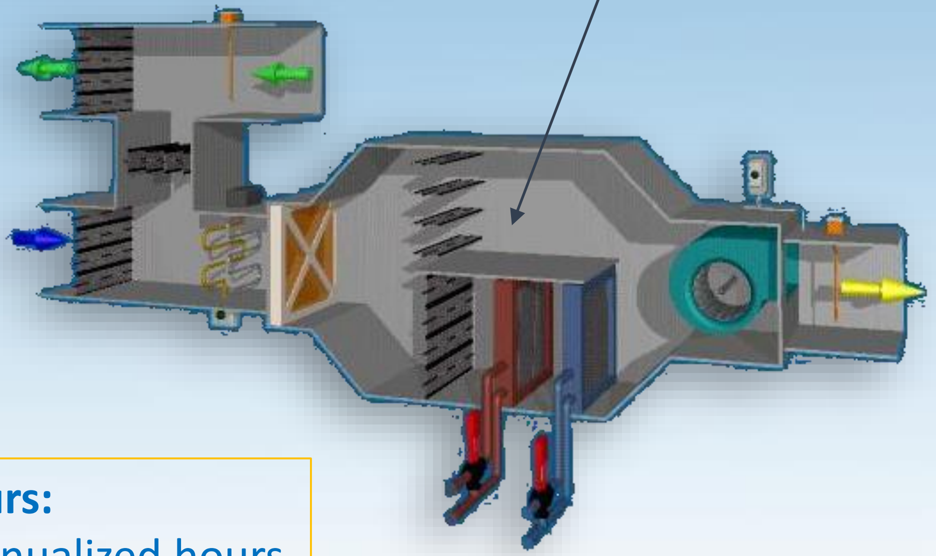


Air Handler Configurations

Energy Savings

Post Heat & Humidity Control:

- Face and bypass
- Side-stream bypass
- Energy recovery
- Desiccant



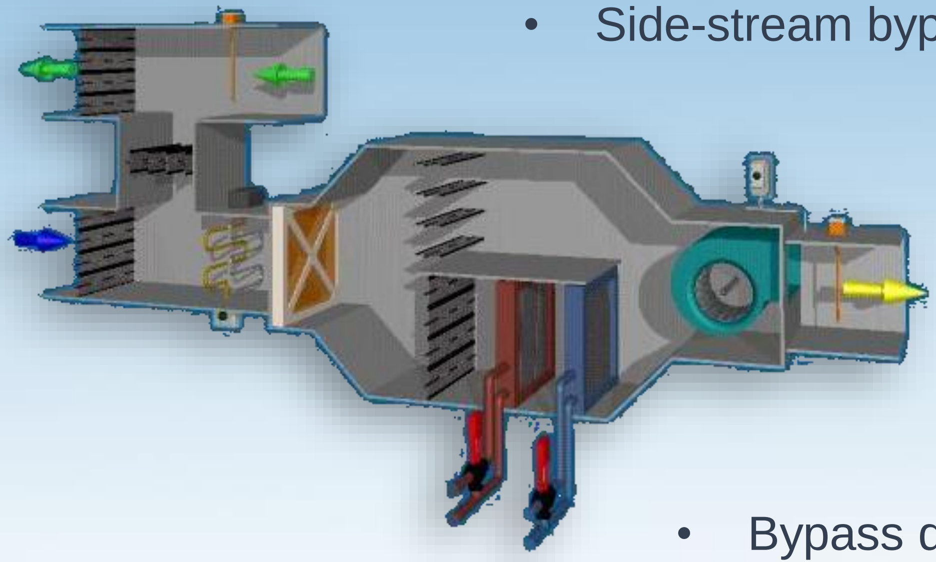
Double economizer hours:

- Phoenix ~ 33-35% annualized hours

Air Handler Configurations

Post Heat & Humidity Control:

- Face and bypass
- Side-stream bypass



Concept:

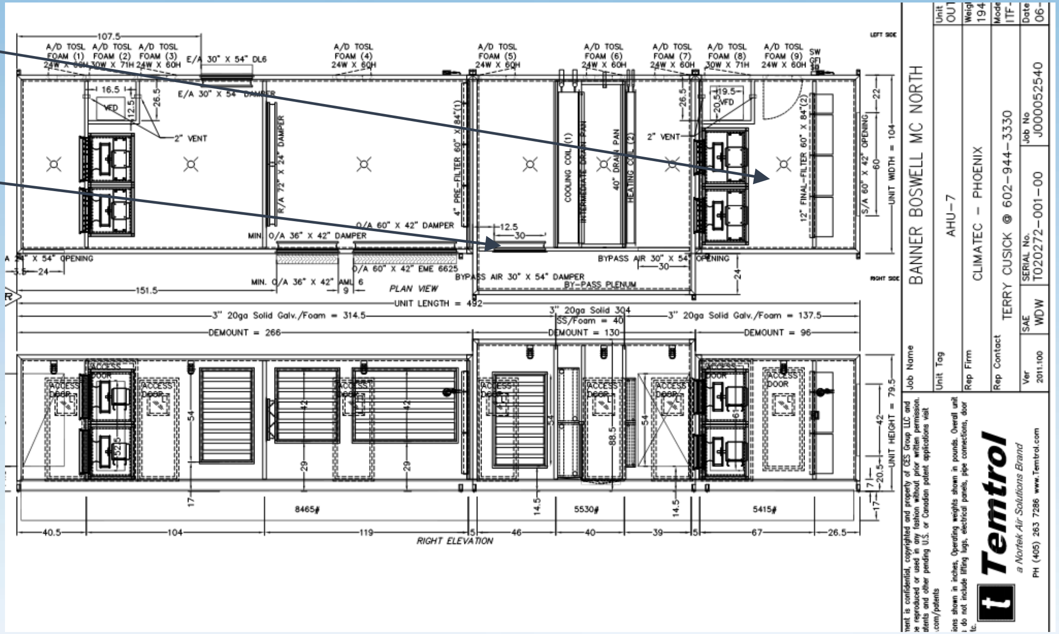
- Dehumidify supply air to required dew point at cooling coil
- Coil bypass provides unconditioned mixed air to post heat off the cooling coil

- Bypass damper position controlled by discharge air temperature sensor

Air Handler Configurations

Supply Air = 65F DB

Side-stream bypass damper



Project: Banner 1 North

- 28 Patient Room Remodel
- AHU Submittal Drawing

Banner Boswell Medical Center

Displacement Ventilation: AHU

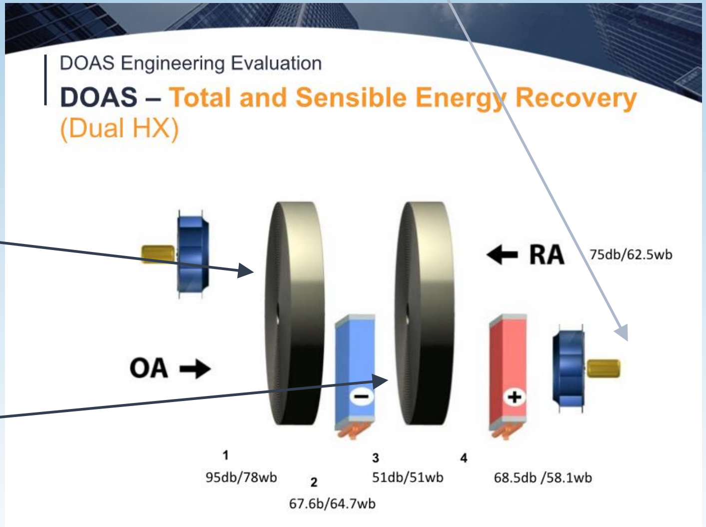
Custom AHU: Dual Wheel Solution

- Enthalpy Wheel for Sensible & Latent Heat Transfer
- Sensible Wheel for Sensible Heat Transfer

Leaving Air Temperature: 65F DB

Enthalpy wheel: Pre-Conditions OSA

Sensible wheel: Post-Conditions SA



Innovative Solutions:
100% Outside Air Solutions

Integrated Design and System Concepts

VARITEC'S ROLE: THE HVAC SYSTEM SOLUTION PROVIDER

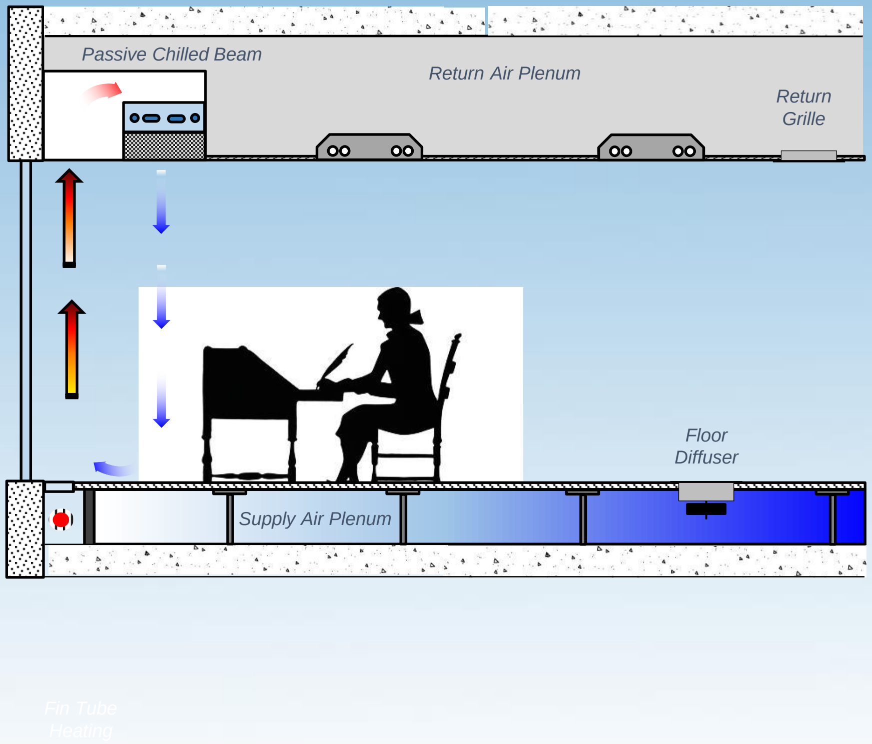
What market changes do you foresee?

Offer holistic solutions to meet these market challenges.

Integrated Design and System Concepts

System Concepts:

- Dilution Solutions:
  - **100% Outdoor Air Systems**
    - Passive Hydronic Designs
      - Chilled Beams
      - Radiant Cooling & Heating
    - Passive Latent Cooling Solutions (Desiccant)
    - Central Plant Load Reduction



Integrated Design and System Concepts

System Concepts

- Variable Refrigerant Underfloor Air Systems
    - VRV coil kit to retrofit AHUs
- VRV with GPS Ionization Technology
- Displacement Ventilation
    - UFAD Systems
    - 40% RH Humidity Control
        - Do particles precipitate more quickly at reduced air turbulence
    - UV lighting
    - Ionization

blended perspectives

- **Integrated Controlled Solutions**

Questions?

Thank you.

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