100% Outside Air Systems: Part #3 – Passive Radiant Heating & Cooling

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

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PREMIER PERFORMANCE THROUGH EDUCATION, DESIGN & INNOVATION

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:**
    - Senior Sales Engineer
        - 2016 - 2022
    - Director of High-Performance HVAC Solutions/Educator
        - 2022 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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VARITEC:
The HVAC System Solution Resource

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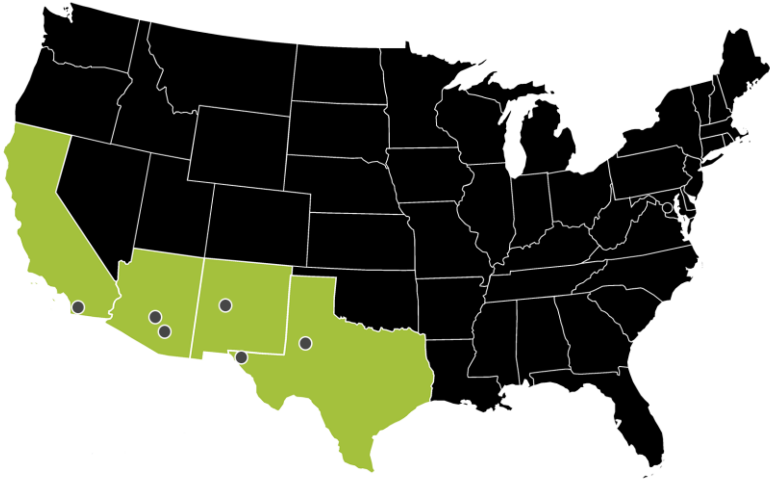
Varitec: The HVAC System Solution

SERVING THE SOUTHWEST
FOR OVER 45 YEARS



Arizona | New Mexico | West Texas | San Diego

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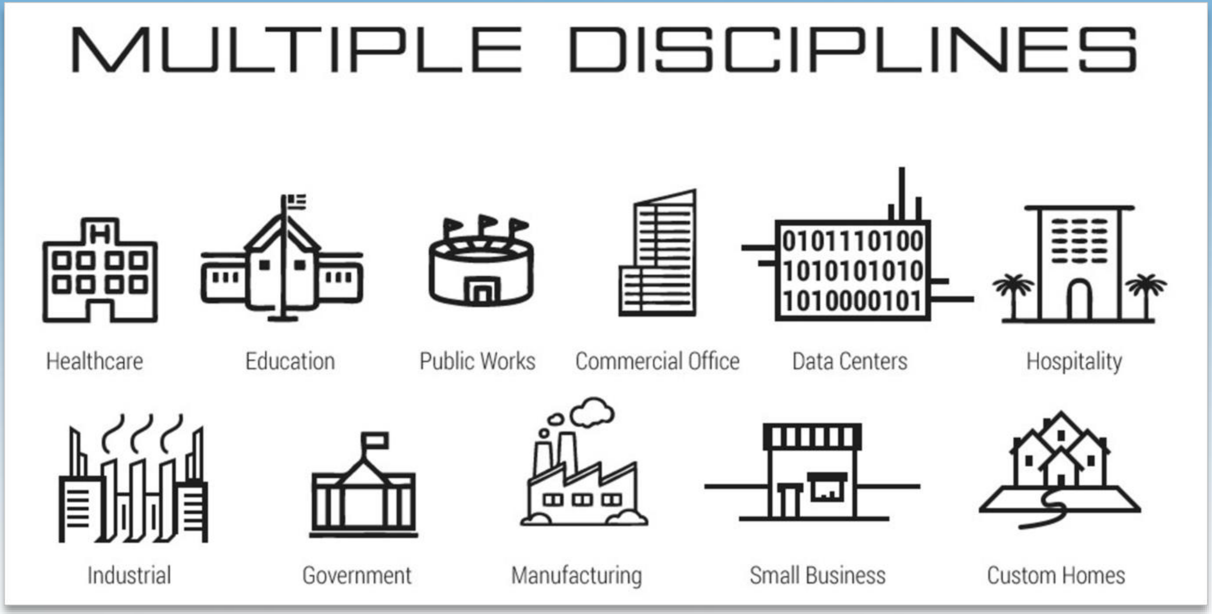
Varitec: The HVAC System Solution



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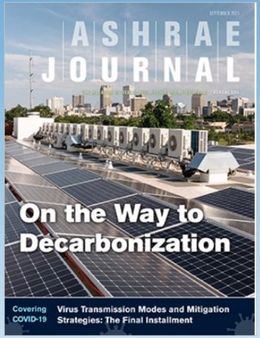
Varitec: The HVAC System Solution

System Solutions:

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

Ventilation: The OSA Challenge

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…"

US Department of Energy

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

Shaping
The Future
Of HVAC

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Mission:

(New Horizons Launch, January 9, 2006)

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.

Varitec Technical Institute

May 12th: Varitec Sustainability Symposium

- Why Buildings Matter

June 15th: Refrigerants: A Global Imperative

July 13th: 100% Outside Air Systems

- Part 1: Variable Refrigerant Systems

September 28th: 100% Outside Air Systems

- Part 2: Active & Passive Chilled Beams

November 30th : 100 Outside Air Systems

- Part 3: Passive Radiant Heating & Cooling Systems

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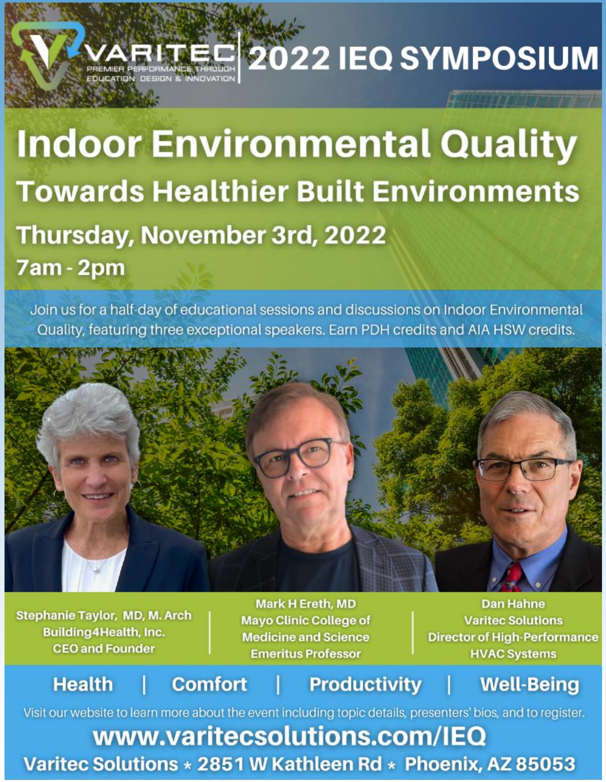
Varitec Technical Institute



Varitec Presents:

Indoor Environmental Quality (IEQ) : Towards Healthier Built Environments Symposium

Date: November 3rd, 2022
Speakers:

- Dr. Stephanie Taylor (B4H Group)
- Dr. Mark Ereth, MD (Mayo Clinic)
- Dan Hahne (Varitec)

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TODAY'S AGENDA

- White House Indoor Air Quality Initiatives
  - IAQ Summit
  - Clean Air in Buildings Website
- HVAC Systems: Modes of Heat Transfer
  - Conventional vs. What If?
- Passive Radiant Cooling & Heating
  - Theory & Concept
- Thermally Stratified Environments:
  - The Air-Side Component
- Passive Radiant Cooling & Heating: Panels & Sails
- Passive Radiant Design Considerations
- Displacement Ventilation DOAS Configurations

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White House Indoor Air Quality Initiatives

White House: Clean Air in Buildings

White House: October 11, 2022 - IAQ Summit

- "…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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White House: Clean Air in Buildings

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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White House: Clean Air in Buildings

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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ASHRAE, CDC & EPA: Air Quality Statements

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**."*

CENTERS FOR DISEASE CONTROL AND PREVENTION

EPA: Introduction to Indoor Air Quality

- **Primary Causes of Indoor Air Quality Problems:**
  - "**Inadequate ventilation** can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources…"

- ***"An important approach to lowering the concentrations of indoor air pollutants… the amount of outdoor air coming indoors..."***

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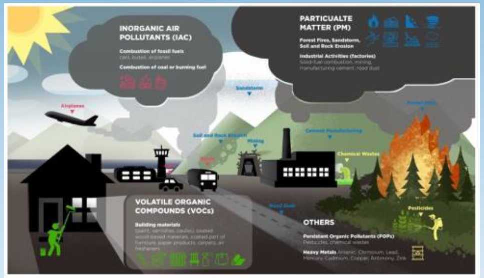
ASHRAE, CDC & EPA: Air Quality Statements

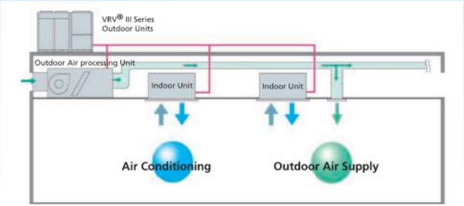
Environmental Protection Agency (EPA):

- **Outdoor Air and Indoor 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)

Buildings contain both indoor and outdoor air contaminants

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ASHRAE, CDC & EPA: Air Quality Statements

Environmental Protection Agency (EPA):

- *"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."***

IEQ APPLICATIONS Column

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ASHRAE Position Document on Indoor CO_2

ANDREW PERSILY, PH.D., FELLOW/LIFE MEMBER ASHRAE; WILLIAM P. BAHNFLETH, PH.D., P.E., PRESIDENTIAL MEMBER/FELLOW ASHRAE; HOWARD KIPEN, M.D.; JOSEPHINE LAU, PH.D., MEMBER ASHRAE; CORINNE MANDIN, PH.D.; CHANDRA SEKHAR, PH.D., FELLOW ASHRAE; PAWEL WARGOCKI, PH.D., MEMBER ASHRAE; LAN CHI NGUYEN WEEKES, P.E., MEMBER ASHRAE

ASHRAE Journal: June 2022

"Of particular interest are several studies providing 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…"

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

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HVAC Systems: Modes of Heat Transfer: Conventional vs. What If?

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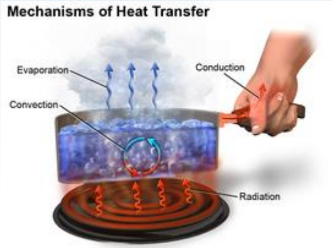
HVAC Systems: Modes of Heat Transfer

HVAC Systems: Review

- To Maintain Thermal Comfort
- To Maintain Indoor Air Quality

HVAC Systems: How?

- **Move air and energy from (cooling) or to (heating) a building**
- **How: Calculate HVAC Total Energy Load to be moved:**
  - **Total Energy (Load) = Sensible Energy + Latent Energy**

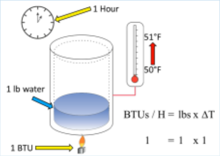


- **Heat Transfer: Four Modes**
  - **Conduction**
  - **Convection**
  - **Evaporation**
  - **Radiation**

HVAC Systems: Modes of Heat Transfer

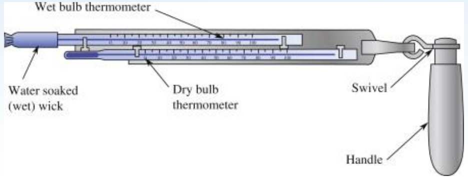
Heat Transfer: Energy Types

- **SENSIBLE HEAT ENERGY: Energy a person "SENSES"**
  - **Sensible energy is the energy measured as Temperature displayed on a thermostat in degrees Fahrenheit (F),** the **"Dry Bulb (DB)"** temperature



LATENT HEAT ENERGY: Humidity (water vapor)

- **Latent energy is the energy required to maintain water in a vapor state (gas).**
- Latent Heat is measured as "**Wet Bulb (WB)**" temperature: Fahrenheit (°F)

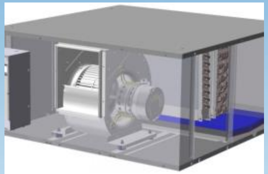


(Sling Psychrometer)

HVAC Systems: Modes of Heat Transfer

Conventional Heat Transfer: All-Air Systems

- **Total Building Load: Present at AHU cooling/heating coils**



(1) ton of energy (load) = 12,000 BTUs total energy

- **Air is the Heat Transfer Medium: (0.46 Btu/lb (Air))**
- **A large volume of air** is needed to move energy from or to a building to maintain space set point conditions

- **Fan motor horsepower required to overcome system resistance**

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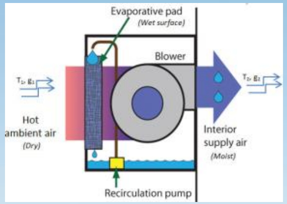
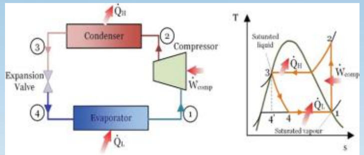
HVAC Systems: Modes of Heat Transfer

Conventional HVAC : All-Air Systems

- **Conditioned air moving through a building transports energy to and from a building.**



(Direct Evaporative Cooler)



(Vapor Compression Cycle)

Mechanically Forced Heat Transfer Modes:

Evaporation:

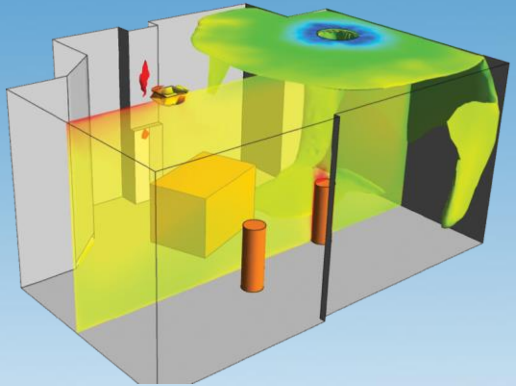
- Direct & indirect evaporative coolers
- Vapor compression cycle:
    - Refrigerant compressors & chillers

- **Conduction:**
    - Heat transfer through heating and cooling coil
    - Energy drawn from airstream (cooling)
    - Energy added to airstream (heating)

HVAC Systems: Modes of Heat Transfer

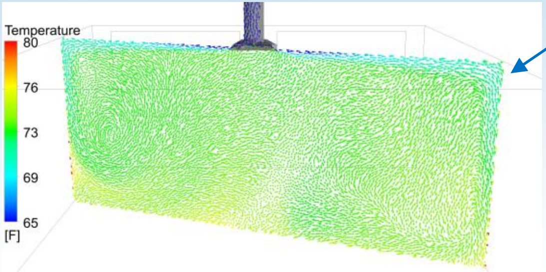
Conventional HVAC : All-Air Systems

- **The Conditioned Space**
  - Condition the cubic volume of space
  - Create mixed-air environments



~75F (+/-2F) DB @ 50% RH (Cooling):
Room Dew Point: 55.13F @ 1100ft elevation

Uniform thermal profile



TOTAL LOAD: AHU Cooling Coil

How:

- **55°F Supply Air (cooling)**
- Diffusers-High discharge velocity **(150 FPM)**
- Mix the entire cubic volume of space for uniform temperature profile (+/- 2F)
- **20F delta T** to satisfy the space load

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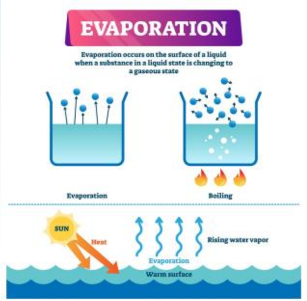
HVAC Systems: Modes of Heat Transfer

Rethinking Heat Transfer – But What If?

(Mechanically Forced Heat Transfer Modes)

(Conduction - Uniform Body)



(Evaporation – Phase Change)

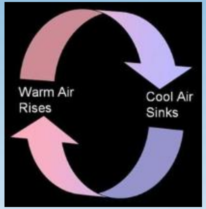
Apply all Four Modes of Heat Transfer:

- **Conduction**
- **Evaporation**
- **Radiation**
- **Convection**

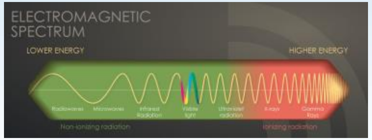
Exploit Properties of Heat Transfer Modes

- Use a More Dense Heat Transfer Medium (Water)
- **Apply the Forces of Equilibrium:** High Energy States Move to Low Energy States

(Passive Approach)



(Convection: Warm Air Rises, Cold Air Falls)



(Radiation – Electromagnetic Spectrum)

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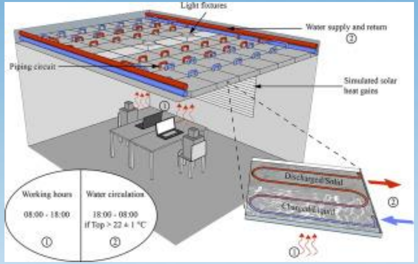
Passive Radiant Cooling & Heating: The Concept

Passive Radiant Cooling & Heating: The Concept

How: Decoupled Passive Hydronic 100% OSA Systems

- **What If?:** Total load **decoupled** into sensible and latent “components”?
- **What If?:** Water is the heat transfer medium?
- **What If?:** Remove or add sensible energy local to each zone using **WATER, NOT AIR?**



Why? Water is More Dense than Air

- Water Has ~**3300 Times More Heat Carrying Capacity** than Air
- Heat Transfer Capacities:
  - **Air – 0.46 Btu/lb (Air)**
  - **Water – 8.98 Btu/lb (Water)**

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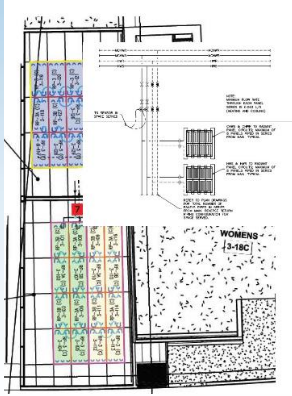
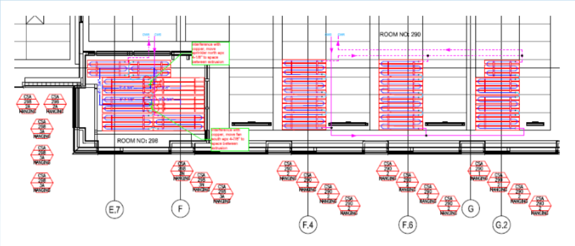
Passive Radiant Cooling & Heating: The Concept

Decoupled Passive Hydronic 100% OSA Systems:

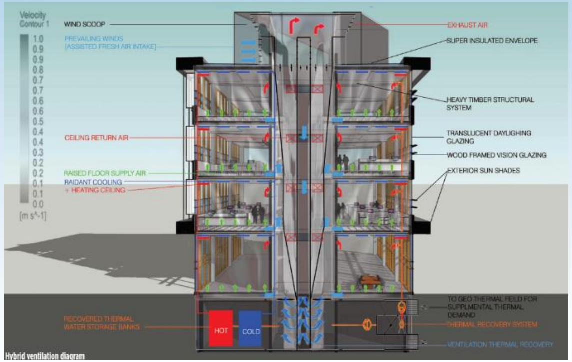
- **Why?: Less Water** required to move same amount of energy as air
- **Why?: Less Heat Transfer Medium**, less ductwork
- **Why?: Less Ductwork**, reduce fan energy required



(Twa: City of Calgary Central Library)



Hybrid Underfloor Air & Radiant Cooling & Heating System



(Twa: Mountain Equipment Co-op Office; Vancouver)

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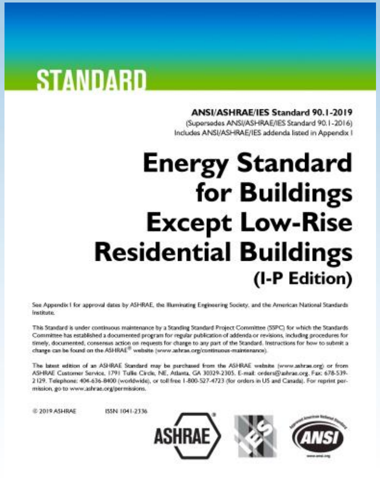
Passive Radiant Cooling & Heating: The Concept

Decoupled Passive Hydronic 100% OSA Systems:

- **Less Fan Energy:** Reduced horsepower
- **Less Horsepower:** Pump HP versus Fan Motor HP
- **Less Energy:** 20-40% Energy Reduction

(Twa: Sparks Center-Telus World of Science)


STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

Energy Standard for Buildings Except Low-Rise Residential Buildings
(I-P Edition)

See Appendix I for approval dates by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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ASHRAE IES ANSI

(ASHRAE Standard 90.1-2019)

How?

- Exploiting physical laws and heat transfer properties to execute work

- **Other Benefits:**
  - **Improved thermal comfort**
  - **100% OSA for improved IAQ**
  - **Same energy moved, less system work**

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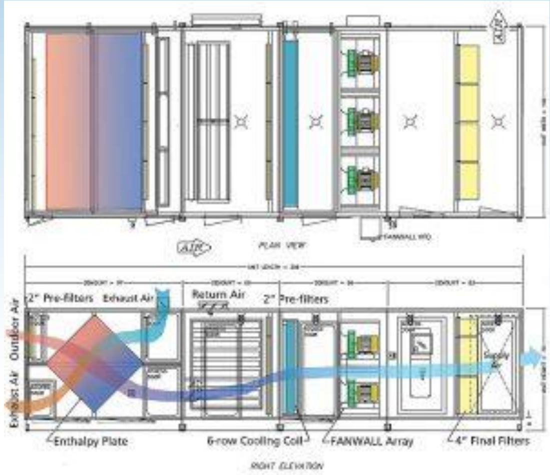
Passive Radiant Cooling & Heating: The Concept

Decoupled Passive Hydronic 100% OSA Systems:

- **System Concept:** Sensible load moved to chilled water loop through radiant panels or sails located in the conditioned space
- Ventilation and Humidity Control: Parallel to and Decoupled 100% Outside Air Unit (DOAS)



Air-Side Component: (Outside Air)

- **Dedicated Outside Air Unit (DOAS)**
- Air Flow Volume Significantly Reduced:
  - ~0.3 to 0.8 CFM depending on zone use
- **Building Humidity (LATENT LOAD) Controlled** by supplying low dew point air (~45-48˚F)

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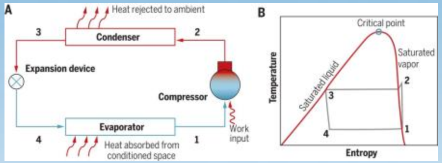
Passive Radiant Cooling & Heating: The Concept

Four Modes of Heat Transfer: Put Physical Laws to Work

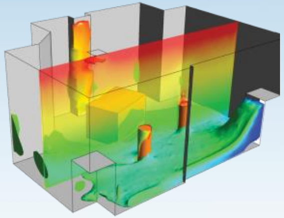
- **Conduction: (Mechanical Force: Fan Energy)**
  - DOAS Cooling & Heating Coils

(Chilled Water Coil)



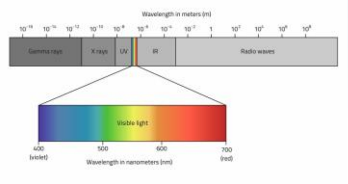
(Vapor-Compression Cycle)

- **Evaporation: (Mechanical Force: Compressor Energy)**
  - Vapor-Compression Cycle: Chillers



(Thermally Stratified Environment)

- **Radiation: (Force of Equilibrium)**
  - Surface **Thermal Asymmetry**: High Energy State moves to Low Energy State



(Electromagnetic Spectrum)

- **Convection: (Force of Equilibrium)**
  - Warm Air Rises, Cold Air Falls

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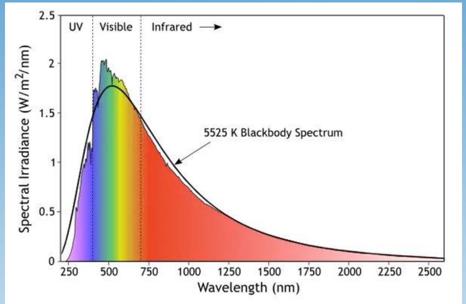
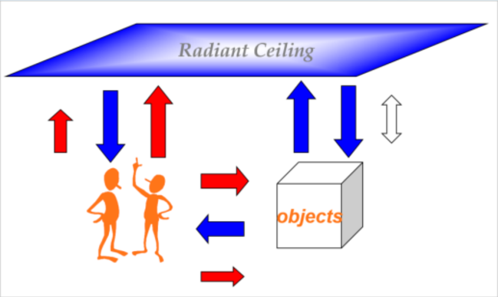
Passive Radiant Cooling & Heating: The Concept

"Passive" Heat Transfer Modes: Radiation

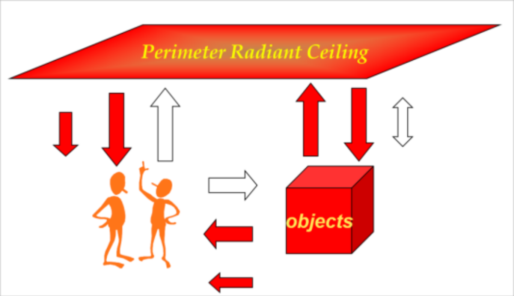
- Electromagnetic Spectrum – Infrared energy
- Surface temperature imbalance:
  - **Chilled Ceilings** absorb heat energy from warm surfaces
  - **Heated Ceilings** Radiate heat energy to cooler surfaces (e.g. perimeter walls)



(Electromagnetic Spectrum: Infrared Energy)



(Radiant "Cooling": Chilled Surfaces)



(Radiant Heating: Heated Surfaces)

Fan energy not required for thermal (sensible) energy heat transfer

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Passive Radiant Cooling & Heating: The Concept

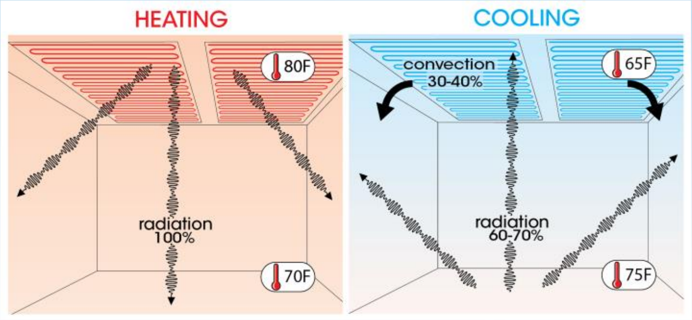
"Passive" Heat Transfer Modes: Radiation & Convection

- **Heat Transfer Terminal Units: Radiant Panels**
- Occupant Radiant Effect: Body temperature of ~98°F
- Occupant surface heat emitted to chilled ceiling or wall

(Radiant Panels)

Improved Thermal Comfort

(Radiant Chilled Ceiling: Telus Spark World of Science)



(Follow the Heat Energy)

Typical Panel Capacity:

- Cooling: 25-30 Btuh/ft²
- Heating: 100-200 Btu/ft²

Cooling Mode: 30-40% convective effect

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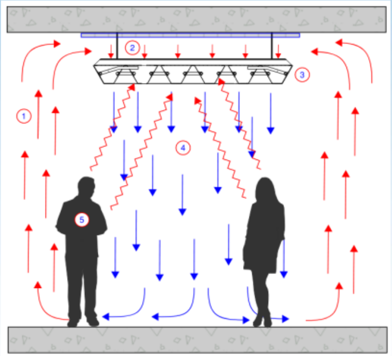
Passive Radiant Cooling & Heating: The Concept

“Passive” Heat Transfer Mode: Radiation & Convection

- **Heat Transfer Terminal Units: Radiant Sails**
- Louvered radiant devices enhance the convective effect, greater cooling capacity **(~50% Radiant / 50% Convective)**

Typical Sail Capacity:

- Cooling: 40-55 Btuh/ft²
- Heating: 80-200 Btu/ft²



(Passive Radiant & Convective Flow Patterns)

- Radiant energy emitted or absorbed by louver blades
- Cool air around chilled sail blades falls via convective forces to the floor
- Free area between sail & deck required for free flow of air

(Norquest College, Alberta)

(Custom Sail Cloud)

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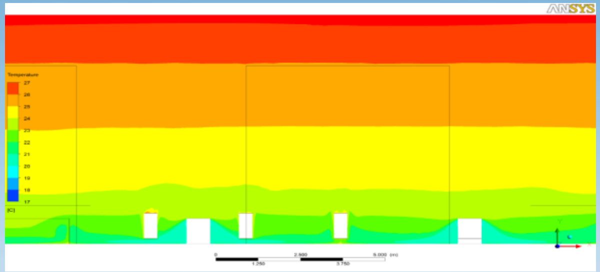
Passive Radiant Cooling & Heating: The Concept

“Passive” Heat Transfer Mode: Convection

- **Maximize heat transfer at radiant device**
- Increase the temperature differential at the radiant panel or sail
- Thermally stratified environments enhance sensible heat transfer via conduction and convection



- **The greater the delta T at the device, the greater the convective flow**

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Thermally Stratified Environments & The Air-Side Factor

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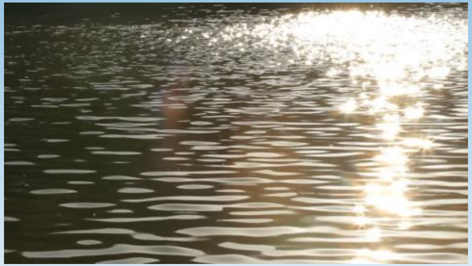
Thermally Stratified Environment & The Air-Side Factor

Thermal Stratification: What is it?

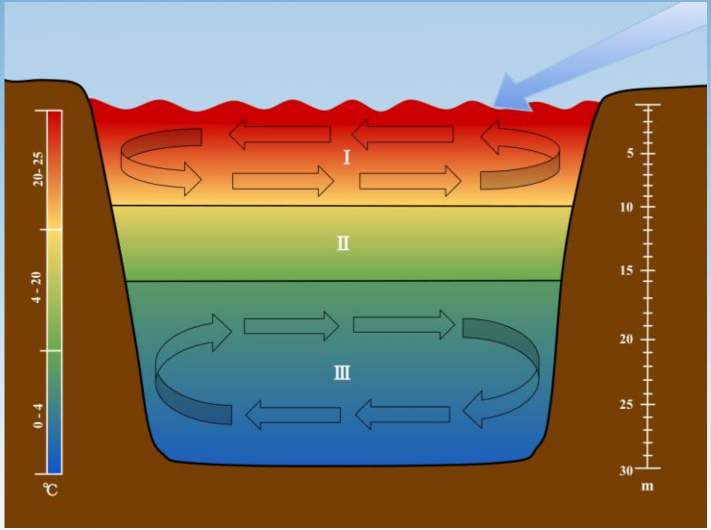
Definition: A temperature differential throughout a continuous body



Body of water:

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

Radiant Lake Effect

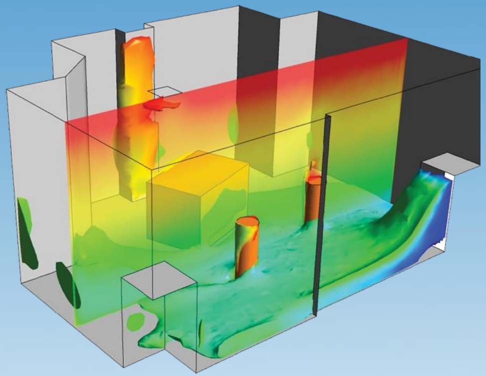


Thermally Stratified Body of Water

Thermally Stratified Environment & The Air-Side Factor

Thermally Stratified Building Space: How?

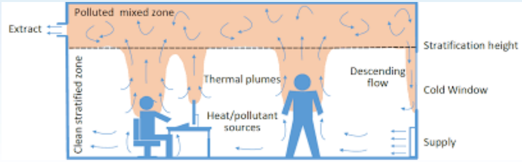
- **Displacement Ventilation:**
  - Supply air at low velocity: **~40 FPM**
  - Supply air temperature: **62-68°F**



(Thermally Stratified Space)

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

- Upper level room air temp: **80-85°F**
- **High level return/exhaust grilles**



Space Air Movement: Applied buoyancy forces (convection)

- Space heat sources: people, lighting, computers…
- Chilled Surfaces: Panels and Sails

Thermally Stratified Environment & The Air-Side Factor

Thermal Stratification & Air Movement

Indoor Air Quality?

Mixed Air

Displaced Air

Single Pass of Clean Conditioned Air Across Occupant Breathing Zones

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Thermally Stratified Environment & The Air-Side Factor

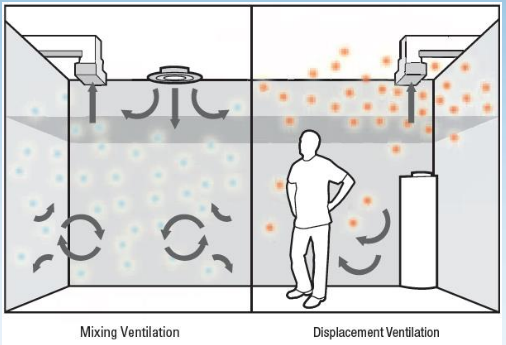
Thermal Stratification & Air Movement

ASHRAE Standard 62.1: Displacement Ventilation (DV):

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

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



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

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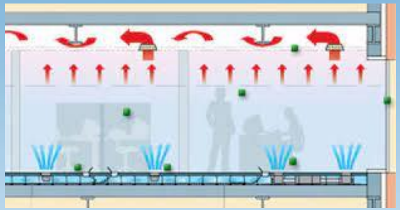
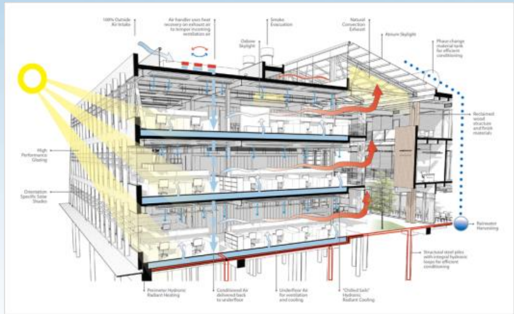
Thermally Stratified Environment & The Air-Side Factor

Room Air Flow Rates: Calculations & Conditions

- **Airflow Rate Calculation: Apply Air-Side Load Fraction***
  - **Definition: Air-Side Load Fraction (ALF)** – The percentage of space sensible load serviced by the primary air to meet ASHRAE Standard 62.1 minimum ventilation requirements.
  - ALF values less than unity "1.0" represents **fan energy savings potential.**
  - The lower the value, the greater the primary air fan energy reduction
  - Values greater than "1.0" may benefit from another HVAC strategy





(Federal Center South Building 102: Seattle, WA.)

Lower ALF demonstrates more sensible load is shifted to the water-side resulting in greater efficiency

*Note: During design phase, this calculation should be performed on a zone-level basis to pre-quality spaces as suitable for de-coupled ventilation.

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Thermally Stratified Environment & The Air-Side Factor

Room Air Flow Rates: Calculations & Conditions

- **Air Flow & Fan Energy Reduction**
  - Majority of energy saved is fan energy; reduced system horsepower
  - Air-Side Load Fraction
    - The smaller the air-side load fraction, the more energy can be saved using radiant system

	Office	Classroom	Lobby
O/A Requirement (cfm/ft²)	0.15	0.5	1
Air Volume (All Air System) (cfm/ft²)	1	1.5	2
Air-side Load Fraction	**15%**	**33%**	**50%**

- ALF = % of sensible load satisfied by ventilation flow rate to meet code or to control space humidity

Suitability Check for Applied Radiant Systems

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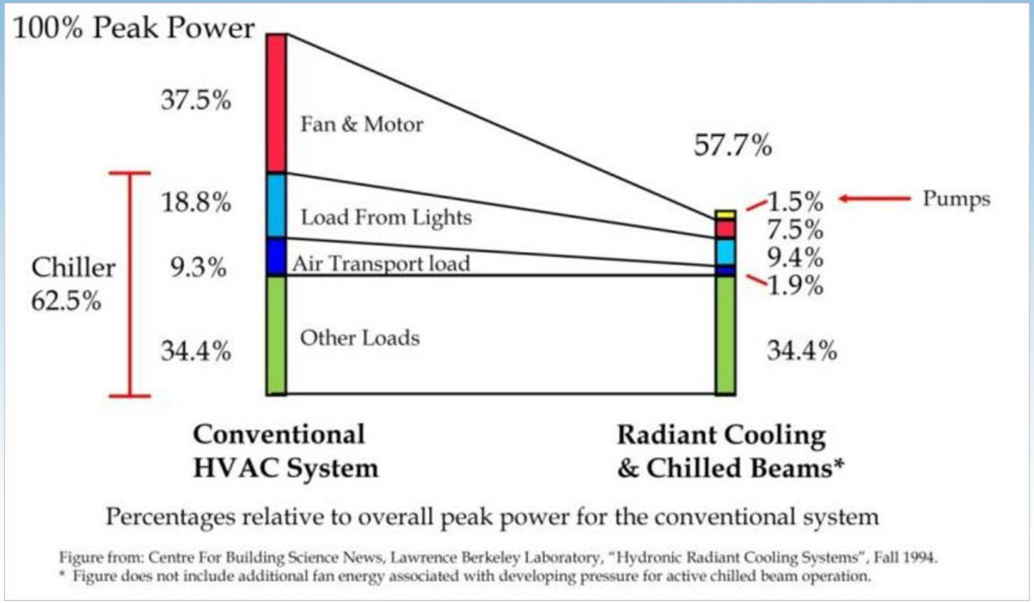
Thermally Stratified Environment & The Air-Side Factor

Room Air Flow Rates: Efficiency Factor

Reduced Fan Use = Reduced Energy



(Superstition Wilderness)

Desert Southwest: Buildings designed to 0.25 to 0.5 CFM/ft^2

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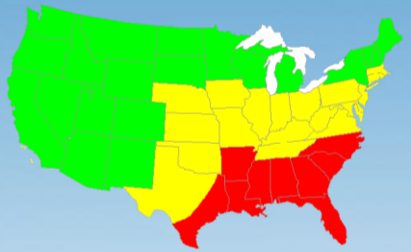
Thermally Stratified Environment & The Air-Side Factor

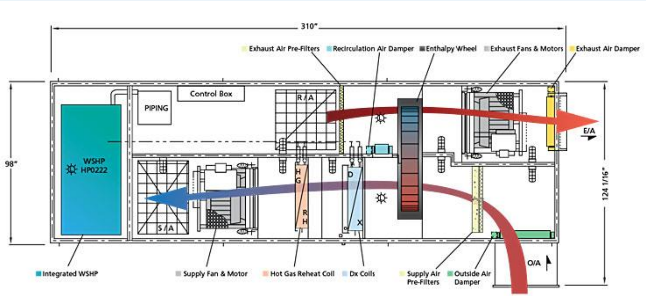
Room Air Flow Rates: Calculations & Conditions

- **100% OSA Design: Meet all Ventilation Factors**
  - Minimum ventilation requirements per ASHRAE 62.1
  - Apply psychrometrics to **remove 100% of all latent loads (humidity)**
  - Maintain building static pressure
  - Supplement sensible loads for zones with higher ALFs



(Green Zone: Dry Climate)

Greatest of These Factors Sets the Minimum Air Flow Rate



- **Dedicated Outdoor Air Unit Layouts**
  - Higher supply air temperatures possible
  - Decreased AHU & building duct sizing
  - Decreased fan energy
  - Building humidity control @ proper supply air dew point

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Thermally Stratified Environment & The Air-Side Factor

Air-Side Design Review:

- **Building Moisture Infiltration:**
  - Perimeter walls
  - Doors to outdoors opening
  - Bathrooms, sinks, kitchen infiltration
- **Maintain Dew Point Control:**
  - Meet 100% of latent load under peak design conditions (Arizona monsoon)
  - Maximum occupancy per zone

(Phoenix Monsoon)

- **Limit Over-Cooling Zones:**
  - Keep air-side fraction low
  - Reset air temperatures for enhanced efficiency
  - CHWS shut-off control or EWT reset
  - VAV for zones with fluctuating occupancy

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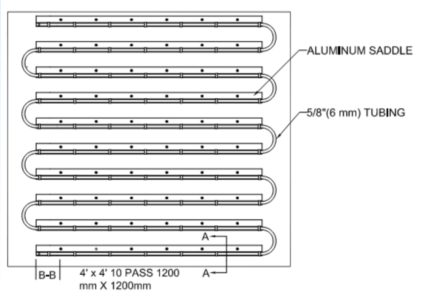
Passive Radiant Cooling & Heating:
Panels & Sails

Passive Radiant Cooling & Heating: Panels & Sails

Radiant Panel Products and Technology:

- **Thermally Activated Panel Construction:**
  - Aluminum extrusions
  - Aluminum sheet metal
  - Steel sheet metal
  - Custom designs – fully integrated ceilings



- **Copper Coils**
  - Serpentine arrangement on back of panels
  - Coils mounted on integrated saddles
  - Mechanically attached at saddle / conductive thermal paste
  - Insulation
  - Acoustical perforations available

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Passive Radiant Cooling & Heating: Panels & Sails

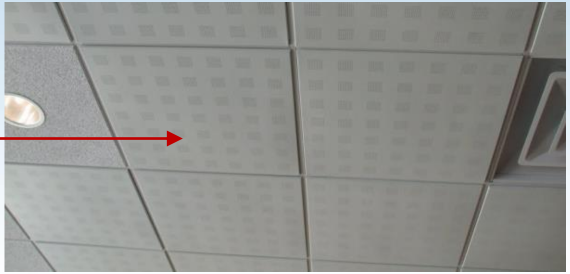
Radiant Panel Products and Technology:

- **Panel Product Types: Surface Options**
  - Castellated – extruded standing ribs
  - Smooth
  - Smooth perforated block
  - Smooth perforated continuous
  - Silk screen to match ceiling

(Castellated with Access Door)

(Smooth Surface Design)

- Full integrated ceiling design with active & inactive panel sections



(Smooth Perforated Block)

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Passive Radiant Cooling & Heating: Panels & Sails

Radiant Panel Products and Technology:

- Ceiling Types: Tegular or T-Bar ceiling grid
- Linear or curved options available
- Radiant clouds
- Security versions available
- Performance testing standards:
  - Heating BSRIA Test Standard 3528: 1977
  - Cooling: DIN EN 14250:2004

(Children's Hospital, Canada)

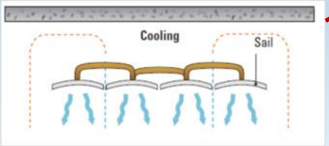
(Open Ceiling Modules)

(Radiant Light Shelfs)

Passive Radiant Cooling & Heating: Panels & Sails

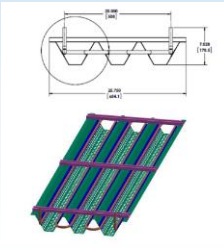
Radiant Sail Products and Technology:

- **Louvered Blade Construction:**
  - High capacity cooling solutions
  - Very high convective air motion, up to 70% of cooling
  - Paint and sublimated dye finishes available

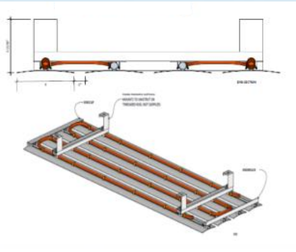


(Norquest College: Edmonton)

- **Parabolic, Linear & Q Sails**
  - Parabolic or flat cross section extruded aluminum fins
  - Perforated and formed aluminum fins



(Q Sails)



(Parabolic Sails)

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Passive Radiant Cooling & Heating: Panels & Sails

Radiant Light Shelf Products and Technology:

- Inactive tops: Allow light to penetrate in (winter) or limit radiant penetration (summer)
- Active top: frost control (winter) or limit radiant penetration (summer)

(Light Shelf)

- **Manage Perimeter Load**
  - Bull nose or corner panels
  - Design features for architectural integration

(Light Shelf)

- **Custom Designs Available:**
  - Component integration (lights, sprinklers)

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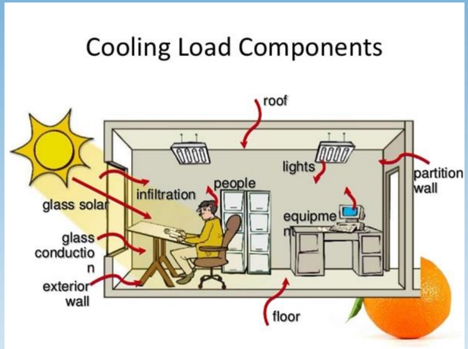
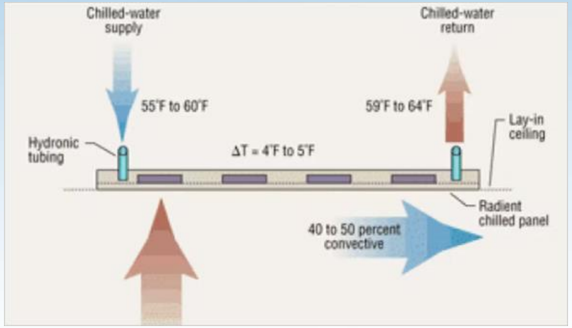
Passive Radiant Design Considerations

Passive Radiant Cooling & Heating: Panels & Sails

Radiant Panels & Sails: Water-Side Design Principles

- **Water-Side Design Parameters:**
  - Water Flow Rate
  - Circuit Pressure Drop
  - Temperatures (EWT, MWT*, LWT)



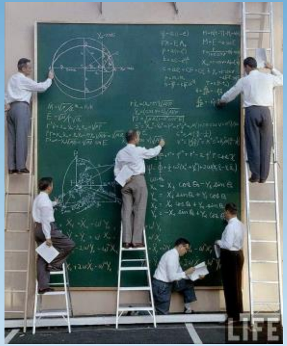


- **Sensible Loads: Design Parameters**
  - Panels & Sails Satisfy High Portion of Space Sensible Loads
  - Coil: ½" diameter nominal

*MWT: Mean wet bulb temperature in space

Passive Radiant Cooling & Heating: Panels & Sails

Radiant Panels & Sails: Water-Side Design Principles



- **Radiant Cooling: Water-Side Parameters**
  - Entering Water Temperature (EWT):
    - Typically between 56 - 62°F
  - Delta T Across the Panel: 4 – 6°F
  - Generally: EWT = 3 - 4°F above space dew point

- **Radiant Heating: Water-Side Design Parameters**
  - EWT Temperature: Typically between 120 - 180°F
  - Delta T across the panel 10 - 30°F

- **Minimum flow rate per circuit** = 0.65 GPM

  Prevent laminar flow (more important for cooling)

*MWT: Mean Wet Bulb Temperature

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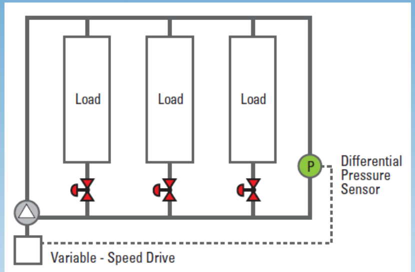
Passive Radiant Design Considerations

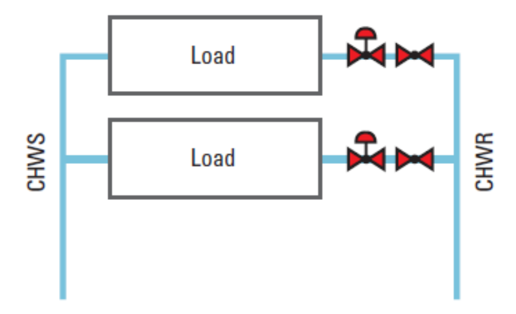
Radiant Panels & Sails: Water-Side Design Principles

Water System: Pressure Control

- Variable speed pump and differential pressure sensor*
- Reduces energy by lowering pump loading



(Variable Speed Pumping)



(Direct Return)

- **Piping Options: *Direct return**
  - Length of pipe varies from supply header to return header for each unit
  - Change in pressure drop from one circuit to another, affects flow rates
  - Use balancing valves or circuit setters

*Note: Can cause imbalances in the system when **not** at full flow if **pressure independent flow control valves are not** used

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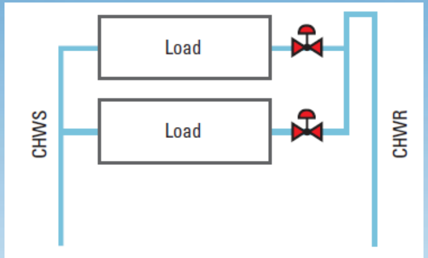
Passive Radiant Design Considerations

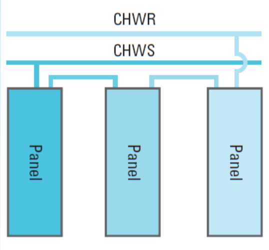
Radiant Panels & Sails: Water-Side Design Principles

Piping Options: Reverse Return*

- First Connection Supplied, Last Connection Return
- Zone or array is self-balancing
- Number of balancing valves can be reduced
- Additional pipe length required



(Reverse Return)



(Series Piping)

Piping Options: Series Piping*

- Used to connect panels in smaller zones
- Reduced piping, valve and balancing costs
- Higher flow rate to maintain Reynolds Number

- **Too many panels in series leads to reduced response and large temperature difference between first and last panel**
- 200ft total of coil piping is upper limit for Delta T and W.P.D.

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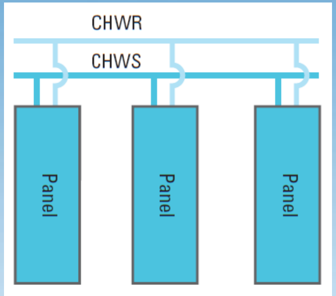
Passive Radiant Design Considerations

Radiant Panels & Sails: Water-Side Design Principles

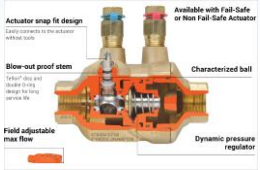
Piping Options: Parallel Piping

- Used with large panels and connecting several sets of panels in series
- Reduced pressure loss
- Lower flow rates to achieve Delta T
- Better temperature distribution and response time



(Parallel Piping)

- **Three Water-Side Design Concerns:**
  - Use of **Glycol** as the operating fluid (especially in cooling)
  - Not considering Pressure Independent flow control valves
    - Especially with large hydronic systems
    - Modulating valves
    - Variable frequency drive pumps
  - Valve & Entrapped air noise



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Displacement Ventilation: DOAS Configurations

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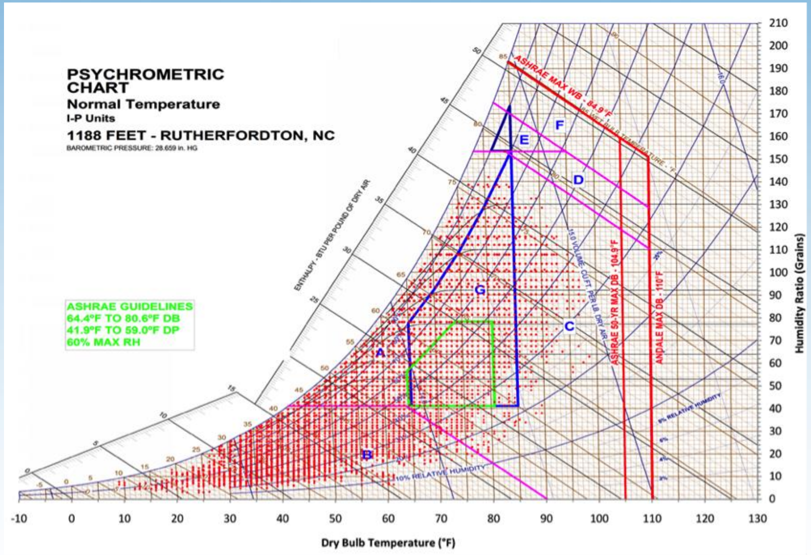
Displacement Ventilation: DOAS Configurations

Displacement Ventilation: AHU Layout

Dehumidification?

- How do you dehumidify 65F supply air?
- What is dew point?
- Outside air designed to control building humidity



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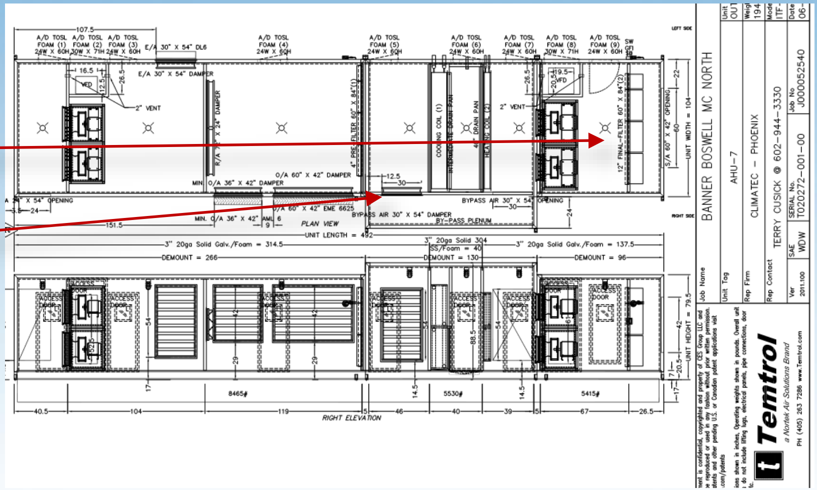
Displacement Ventilation: DOAS Configurations

Displacement Ventilation: AHU Layout

Supply Air = 65F DB

Side-stream bypass damper



Project: Banner 1 North

- 28 Patient Room Remodel
- AHU Submittal Drawing

Banner Boswell Medical Center

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Displacement Ventilation: DOAS Configurations

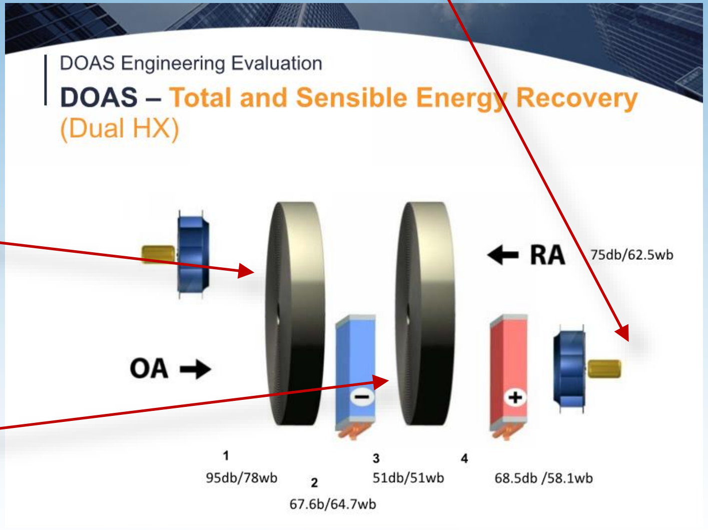
Custom AHU: Dual Wheel Solution

- 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



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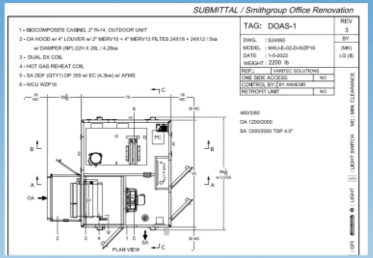
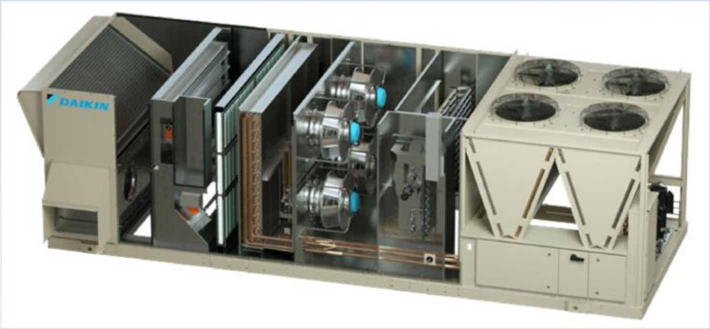
Displacement Ventilation: DOAS Configurations

Custom Package DX Equipment with Hot Gas Reheat

- Enthalpy Wheel for Sensible & Latent Heat Transfer
- Cooling coil dehumidifies and hot gas reheat coil post heats supply air.



(Custom DX Layouts)



(Rooftop DX with Variable Speed Compressors)

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Central Plant Optimization

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EDUCATION, DESIGN & INNOVATION

Central Plant Optimization

Daikin – Air Cooled Chillers

- Pathfinder – 165 to 550 tons
- Variable volume compressor ratio design for efficiency
- Quiet operation using single rotor design and built in muffler
- Restore cooling in 35 seconds
- Can reach full capacity in less than 4 minutes
- LWT up to 65F

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Central Plant Optimization

Daikin Model AWV18A 200 Ton
Air Cooled Chiller Performance

- 115F degree ambient
- Chilled Water:
  - EWT: 54F
  - LWT: 44F

PATHFINDER® Air-Cooled Screw Chiller DAIKIN

Unit Performance

Design			
Capacity	Input Power	Efficiency	IPLV.IP*
200.0 ton	298.5 kW	8.000 EER	21.30 EER

Performance Points rated at AHRI Ambient Relief

Unit							Evaporator				Condenser	
Point #	% Load	Capacity ton	Input Power kW	Efficiency EER	Economizer Status #1; #2	Compressor RPS #1; #2	Fluid Flow gpm	Pressure Drop ft H_2O	Entering Fluid Temperature °F	Leaving Fluid Temperature °F	Ambient Air Temperature °F	Altitude ft
1	100.0	200.0	298.5	8.000	N/A	84; 54	477.5	13.2	54.00	44.00	115.0	1100
2	75.0	150.0	133.1	13.50	N/A	52; 35	477.5	13.2	51.50	44.00	92.5	1100
3	50.0	100.0	54.60	22.00	N/A	32; 22	477.5	13.2	49.00	44.00	70.0	1100
4	25.0	50.00	20.00	29.90	N/A	26	477.5	13.2	46.50	44.00	55.0	1100

** IPLV reflects AHRI standard rating conditions and may change with user defined conditions due to AWV product optimized configurability.*

Daikin Model: AWV018A (18 Condenser Fans)

- DC inverter duty condenser fans
- Chiller Efficiency (EER): 10.60 Btu/W.h
- Chiller Part Load Efficiency: IPLV = 21.30 Btu/W.h
- More air increases chiller efficiency

VARITEC
PREMIER PERFORMANCE THROUGH EDUCATION, DESIGN & INNOVATION

Central Plant Optimization

Daikin Model AWV18A 200
Ton Air Cooled Chiller Performance

- 115F degree ambient
- Chilled Water:
  - EWT: 65F
  - LWT: 55F

PATHFINDER® Packaged Air-Cooled Screw Chiller — DAIKIN

Unit Performance

Design			
Capacity	Input Power	Efficiency (EER)	IPLV.IP* (EER)
190.5 ton	215.1 kW	10.60 Btu/W.h	22.20 Btu/W.h

Performance Points rated at AHRI Ambient Relief

Unit							Evaporator				Condenser	
Point #	% Load	Capacity ton	Input Power kW	Efficiency (EER) Btu/W.h	Economizer Status #1; #2	Compressor RPS #1; #2	Fluid Flow gpm	Pressure Drop ft H_2O	Entering Fluid Temperature °F	Leaving Fluid Temperature °F	Ambient Air Temperature °F	Altitude ft
1	100.0	190.5	215.1	10.60	On; On	47; 42	456.1	12.1	65.00	55.00	115.0	1100
2	75.0	142.9	102.0	16.80	On; Off	33; 31	456.1	12.1	62.50	55.00	92.5	1100
3	50.0	95.30	42.90	26.70	Off; Off	22; 20	456.1	12.1	60.00	55.00	70.0	1100
4	25.0	47.60	18.80	30.40	Off; Off	20	456.1	12.1	57.50	55.00	55.0	1100

** IPLV reflects AHRI standard rating conditions and may change with user defined conditions due to AWV product optimized configurability.*

Daikin Model: AWV018A (18 Condenser Fans)

- DC inverter duty condenser fans
- Chiller Efficiency (EER): 10.60 Btu/W.h
  - Chiller Part Load Efficiency: IPLV = 22.20 Btu/W.h
- More air increases chiller efficiency

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100% Outside Air Systems
&
Active & Passive Chilled Beams

Review

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Presentation Review

- White House Indoor Air Quality Initiatives
  - IAQ Summit
  - Clean Air in Buildings Website
- HVAC Systems: Modes of Heat Transfer
  - Conventional vs. What If?
- Passive Radiant Cooling & Heating
  - Theory & Concept
- Thermally Stratified Environments:
  - The Air-Side Component
- Passive Radiant Cooling & Heating: Panels & Sails
- Passive Radiant Design Considerations
- Displacement Ventilation DOAS Configurations

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Questions?

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Thank you.

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