Chilled Beam Systems and the 2016 WSEC

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Titus
Redefine your comfort zone.™

2016-2017 WSEC Changes

Code Language Changes

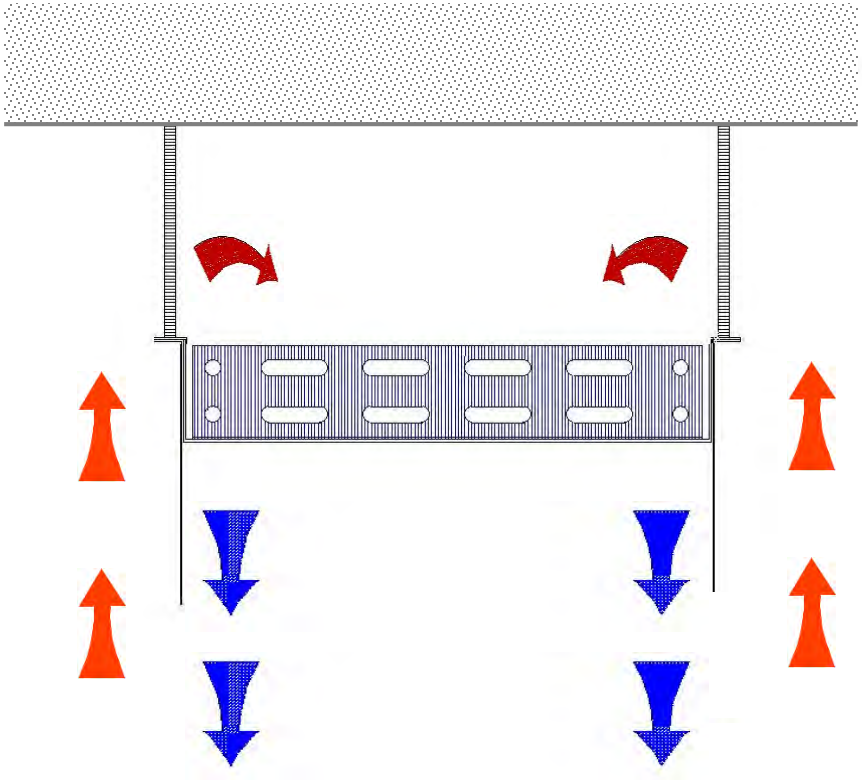
- Ventilation (C403.2.6)
  - Ventilation airflow not to exceed ASHRAE 62.1 minimum by more than 50%
  - Exception where ERV (C403.5.1) is provided (required when over 5,000 CFM)
- DOAS for ventilation air (C403.6)
  - Dedicated AHU and ductwork for ventilation air without operation of heating/cooling fans
  - Practically eliminates conventional VAV systems by requiring separation of ventilation air
  - Cooling/dehumidification supplemented at zone level
  - Exception for high efficiency VAV systems (C403.7)
- Economizers (C403.3)
  - Air economizers shall be provided on all new systems…
  - Exceptions
    - Systems complying with section C403.6 (DOAS)
    - Water cooled refrigeration equipment utilizing cooling towers
    - VRF and (?) fan coil systems

Chilled Beam Types

Passive chilled beams

Active chilled beams

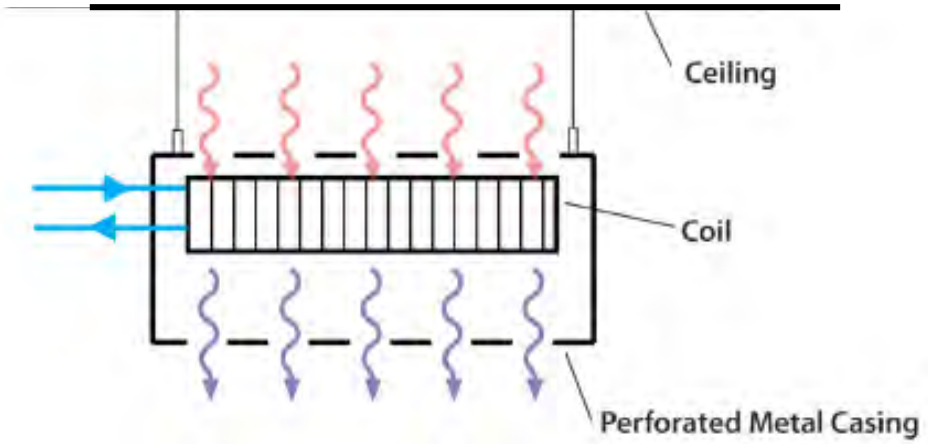
Passive Chilled Beams



- Passive beams are typically 4 to 6 FPI

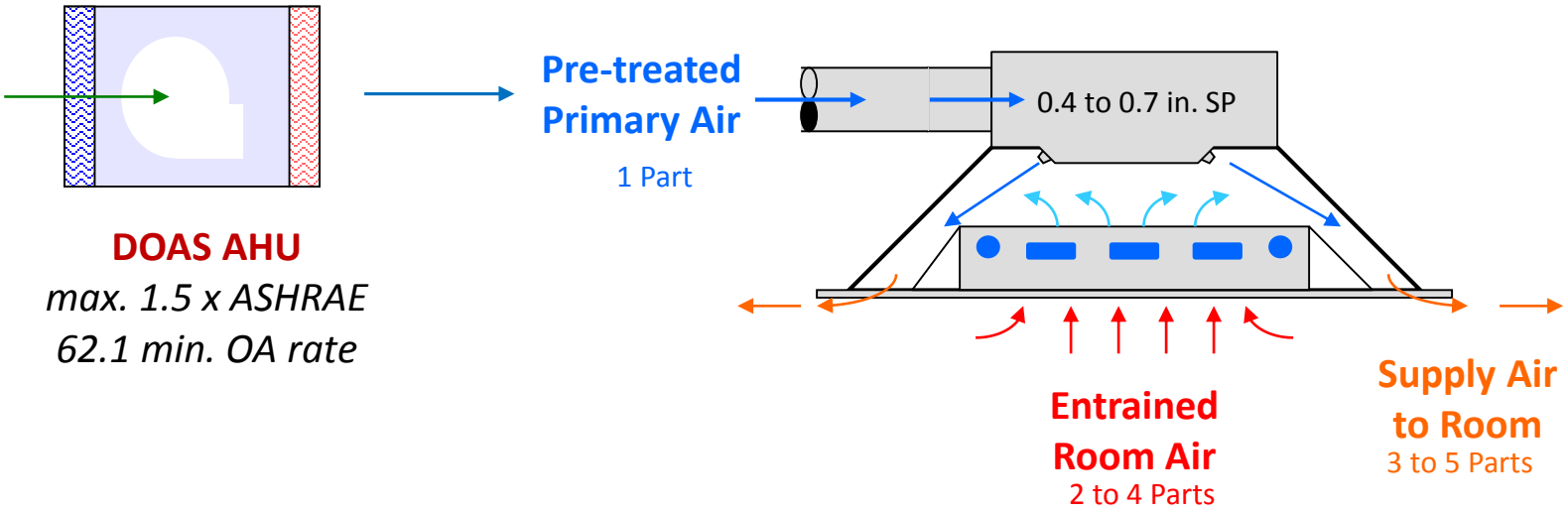
- Passive beams are not radiant cooling devices
- Passive beams are not effective for heating
- Require separate ventilation source

Types of Passive Beams



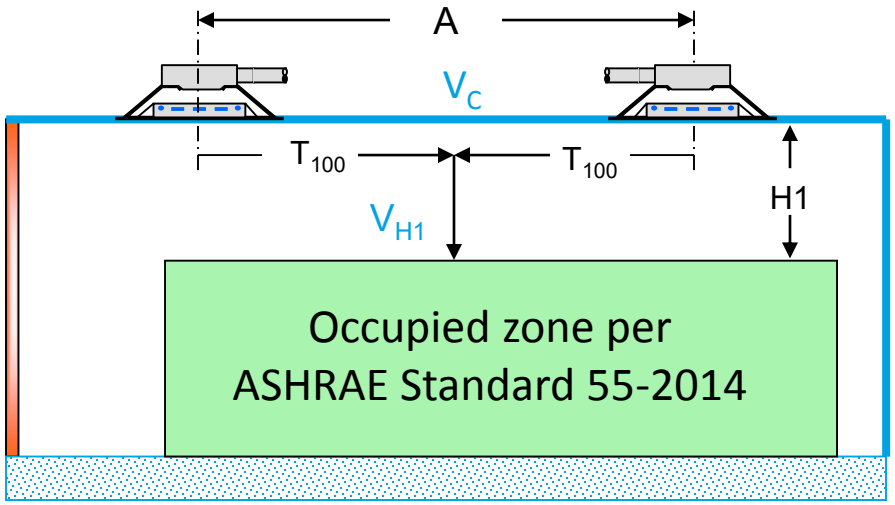
- Sensible cooling only
- Recessed or exposed mounting

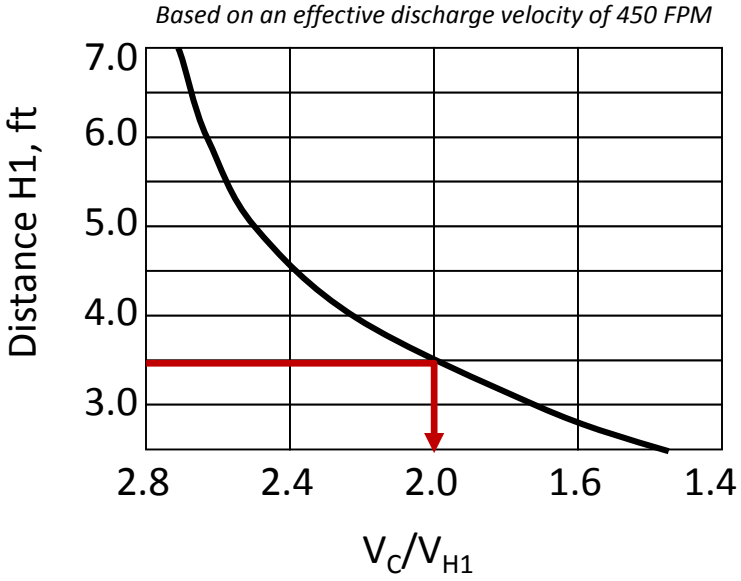
Active Chilled Beams

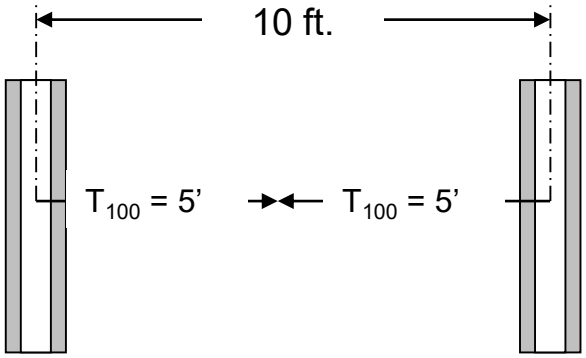


- *When properly selected, constant volume supply airflow rate ensures ASHRAE Standard 55-2014 compliance.*
- *Consistent air distribution performance eliminates dumping*

Placement of Active Beams





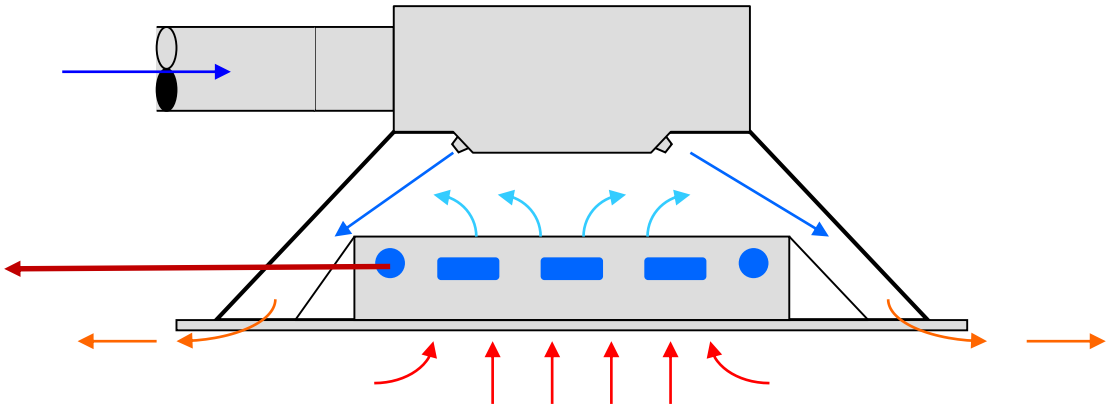


- For the velocity entering the occupied zone 3½ feet below the plane of discharge to be less than 50 FPM, the collision point velocities must be less than 100 FPM
- If T_{100} = 5 feet, the outlets must be spaced at least 10 feet on center

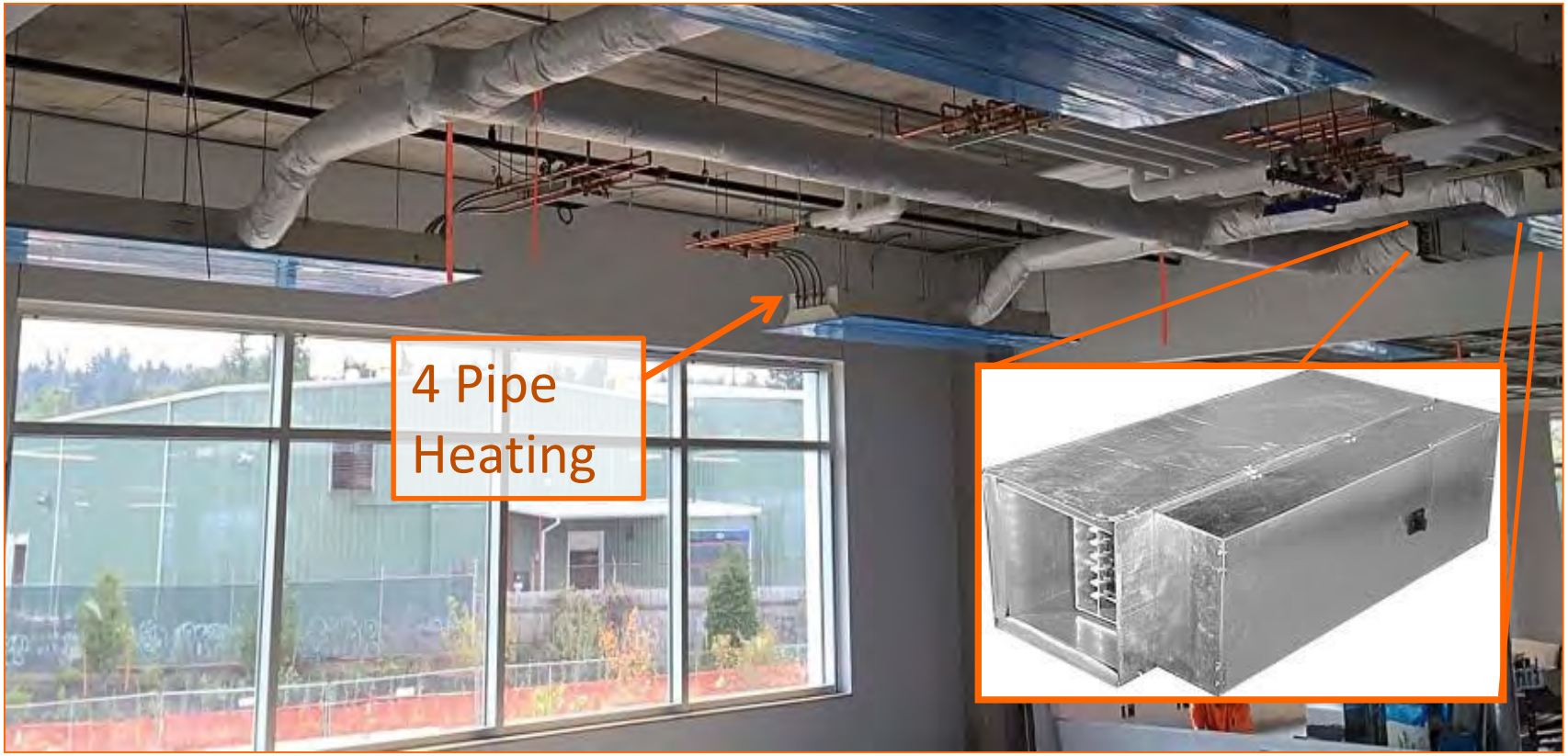
Sensible Cooling with Active Beams

60 to 80% reduction in primary airflow

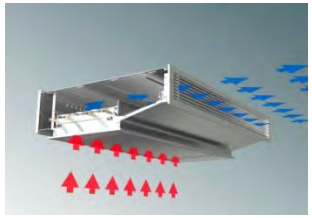
60 to 80% of space sensible heat removal by water

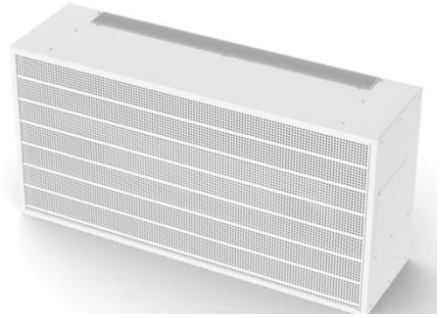


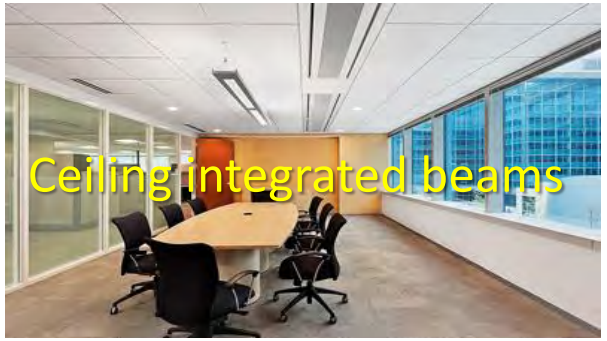
Heating with Active Beams



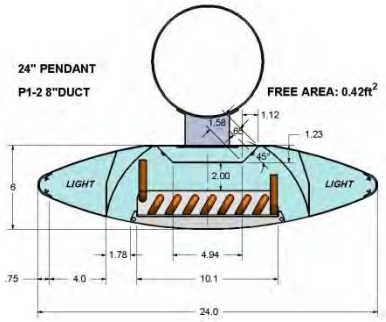
Types of Active Beams

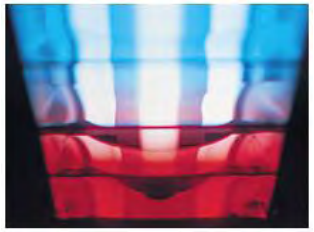


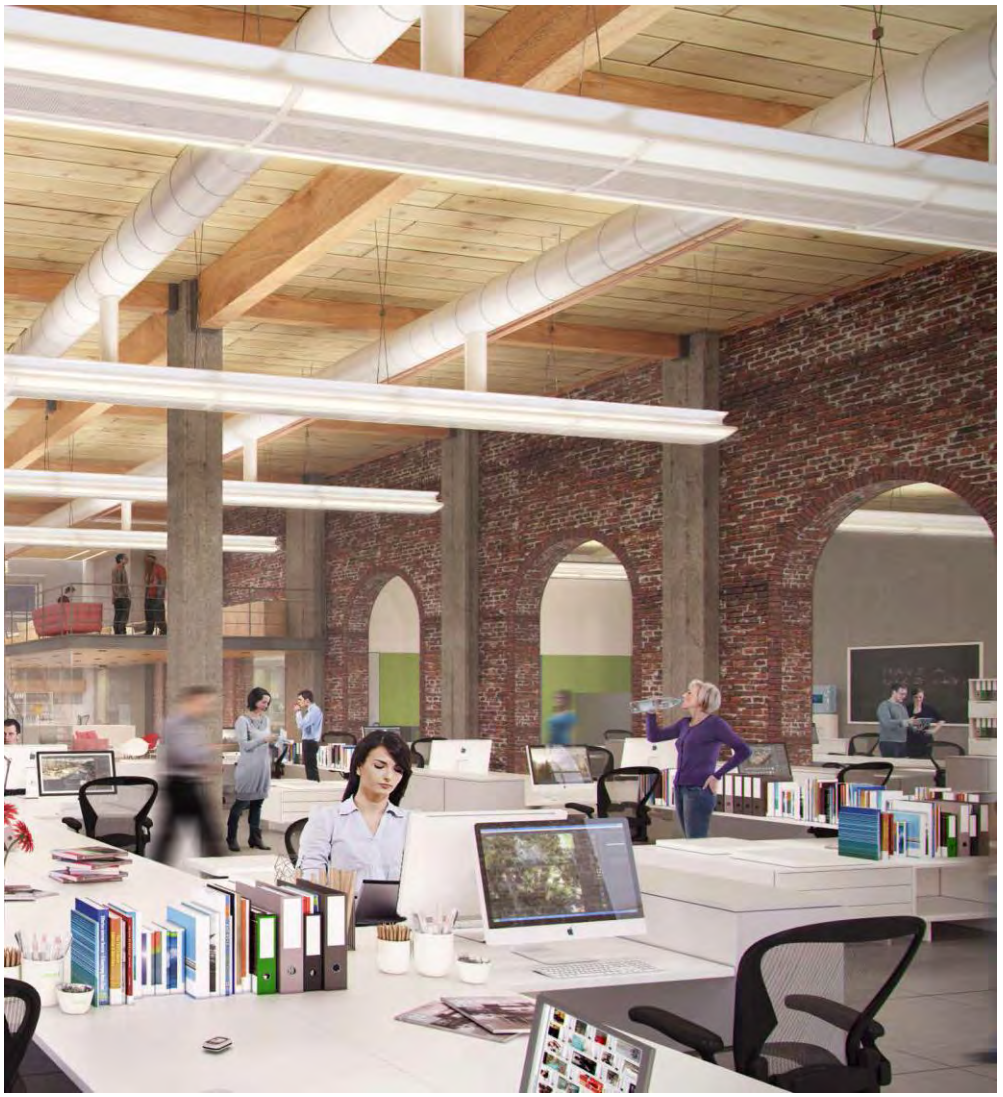




Multiservice Chilled Beams

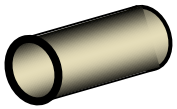




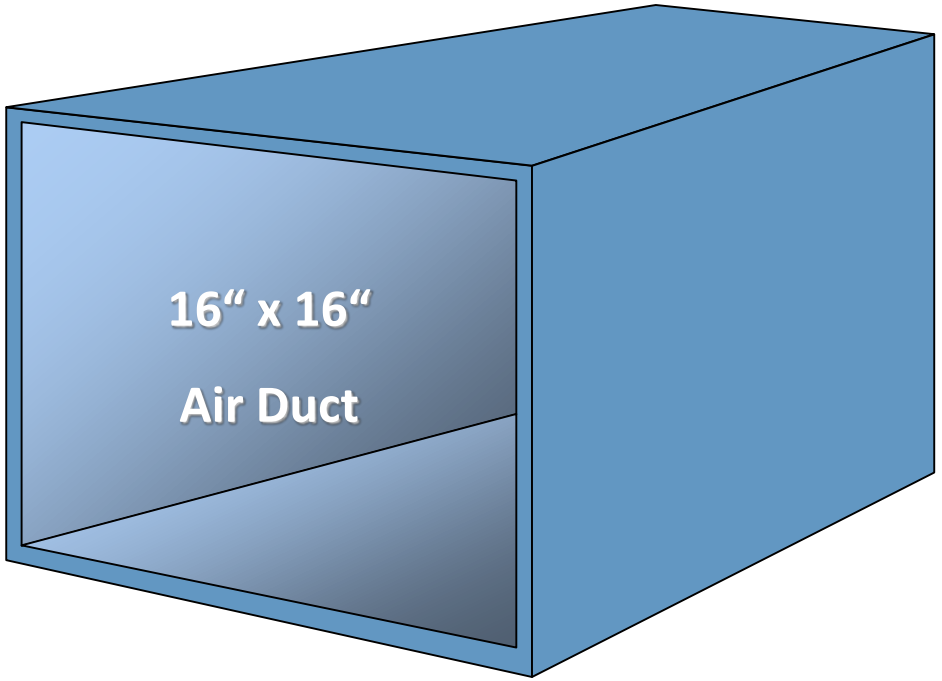


WHY BEAMS?

Why Chilled Beams



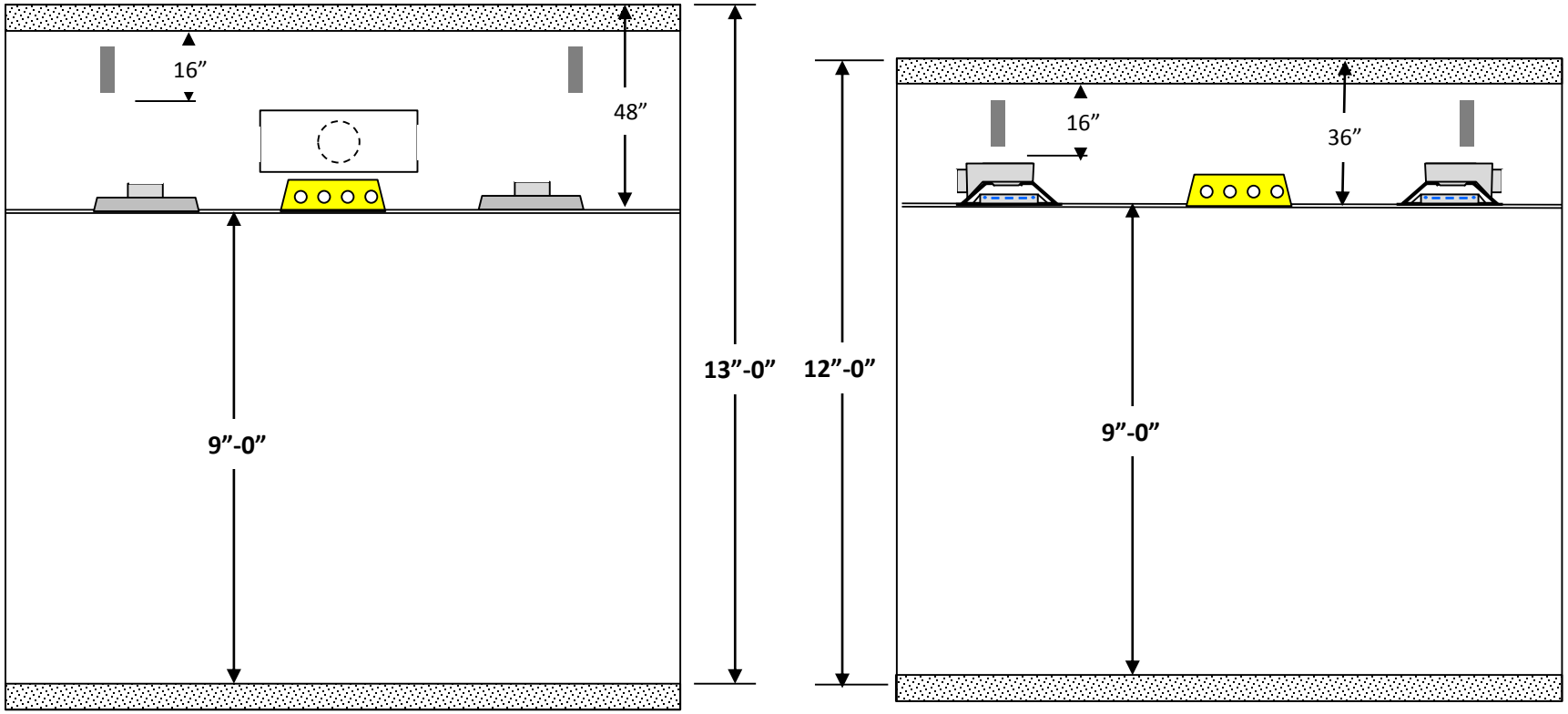
1“ Dia. Water Pipe



Water density is 800 times that of air

Water heat transfer capacity is 3,500 times that of air on a mass basis!

Architectural Savings



Impact of Reduced Slab Spacing

Structural steel	$7,200
Curtain wall	$10,500
Fire proofing	$600
Air barrier	$8,787
Insulation	$7,200
Exterior caulking	$1,522
Masonry (interior & exterior)	$97,692
Dry wall	$55,249
Steel studs	$22,824
Stairs	$2,500
Elevators	$5,000
Electrical	$30,000
Total cost savings	$245,298

- Viterbo University (LaCrosse, WI)
- 65,000 ft^2 building, 5 floors
- Reduction of 12” per floor
- **Structural savings of $3.77 per square foot**

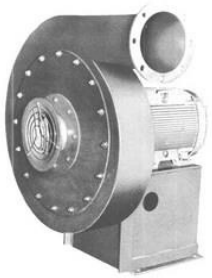
Source: Pope and Leffingwell of HGA, Inc. and Bauer of Butler-Fetting Co.
ASHRAE CRC presentation

Space Savings

- Ductwork and component sizes
  - Duct area reduced by 50 % or more
  - Supply and return chases reduced by 50%

- Air handling units
  - AHU footprint reduced 30 to 40%
  - Weight reduction to structure
  - Increase in usable floor space

Transport Energy Comparison



$$BHP = \frac{CFM \times SP}{6{,}356 \times FAN_{EFF}}$$

555 CFM = 1 Ton

Assuming fan SP = 3 in. H_2O

Assuming fan eff. = 75%

BHP (to move 1 Ton) = 0.35

$$BHP = \frac{GPM \times HD}{3{,}960 \times PUMP_{EFF}}$$

4 GPM = 1 Ton

Assuming pump HD= 40 ft. H_2O

Assuming pump eff. = 75%

BHP (to move 1 Ton) = 0.05

Energy Savings

- Air handling unit operating cost
  - BHP typically reduced by 50%
  - Fan energy savings of 40 to 70%

- Chiller operating cost
  - Higher return water temperature to chiller increases COP by 2 to 4% per degree
  - Dedicated chiller COP increased by up to 40%

Maintenance Costs

- No filtration required
  - Low face velocities, dry coil surface
  - Maintenance savings $100 per beam-year
- No blowers/motors
  - Motor life expectancy 8 to 10 years
  - Cost of replacement $450 to $500
- Low cost of ownership
  - Significant energy savings
  - Minimal maintenance and repair

Chilled Beam Applications

Chilled Beam Applications

Where to Use Them

Anywhere you can control the indoor humidity

- Laboratories
- Office buildings
- Educational facilities
- Government facilities
- Health care facilities

Ideal Applications

- Limited plenum space
- Applications with conflict between sensible cooling and ventilation demand

Where Not to Use Them

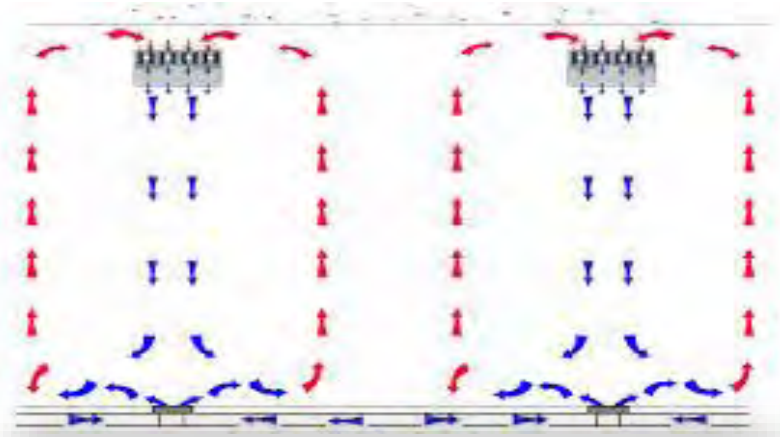
Spaces where indoor humidity *cannot* be controlled

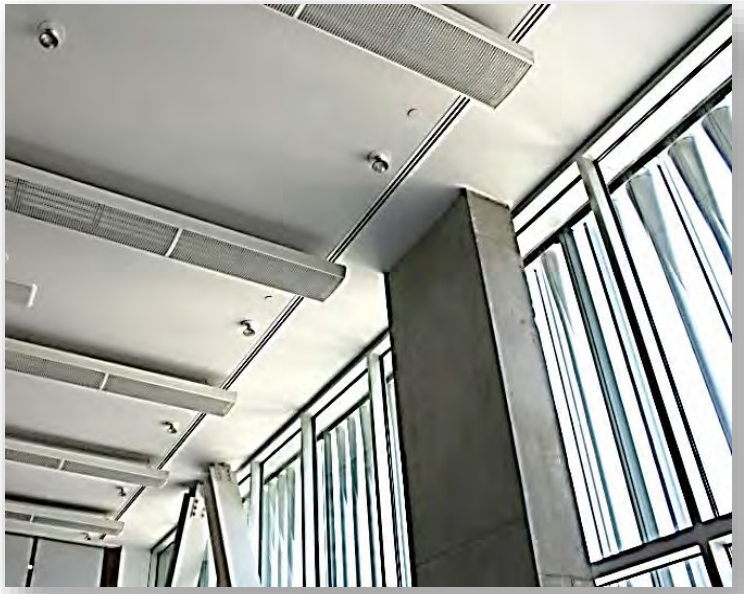
- Kitchen and bathroom areas
- Other areas with low sensible heat ratios

Use Them with Caution

- Rooms with operable windows
- Entrance lobbies/atriums

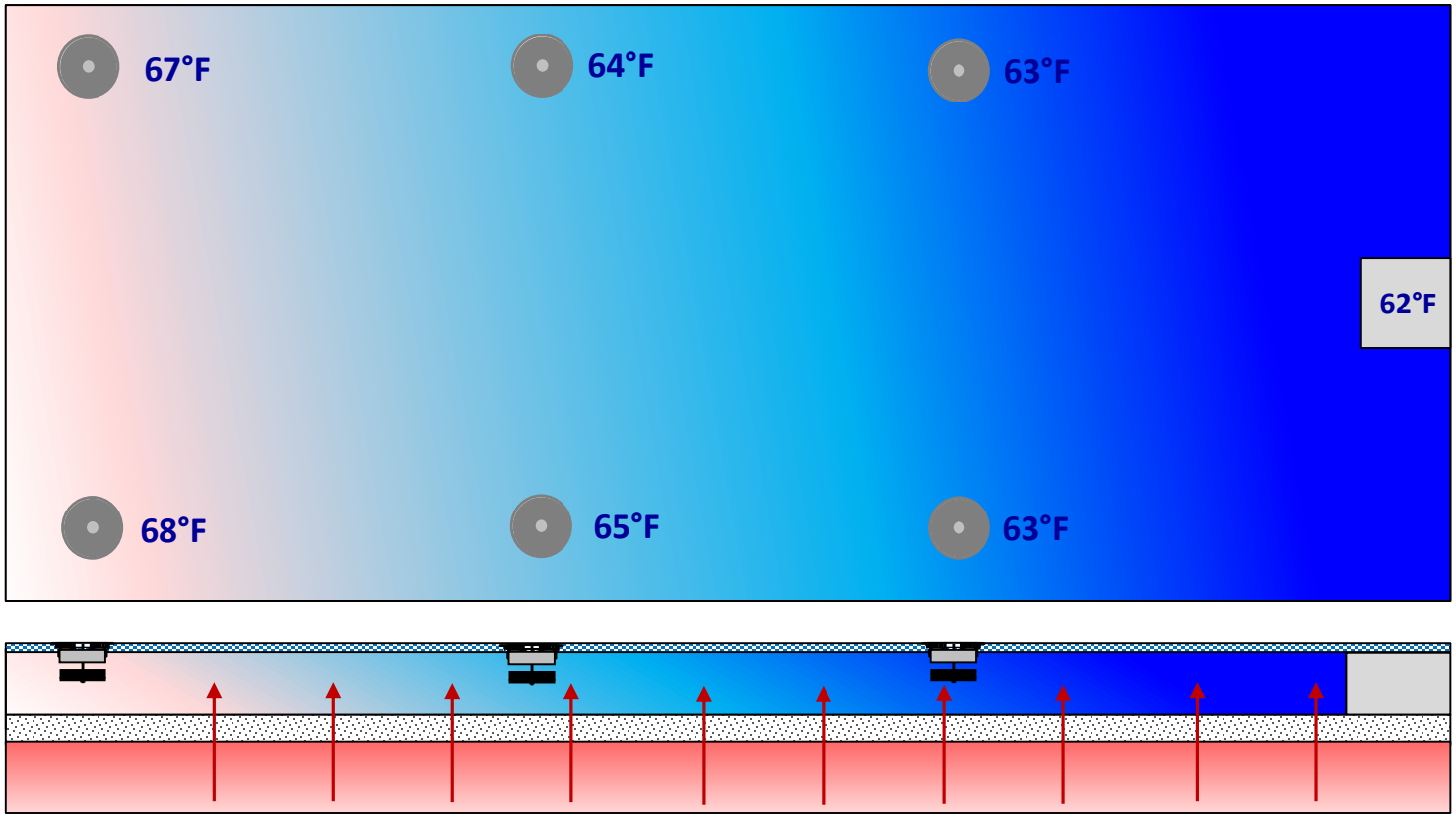
Passive Beams with UFAD



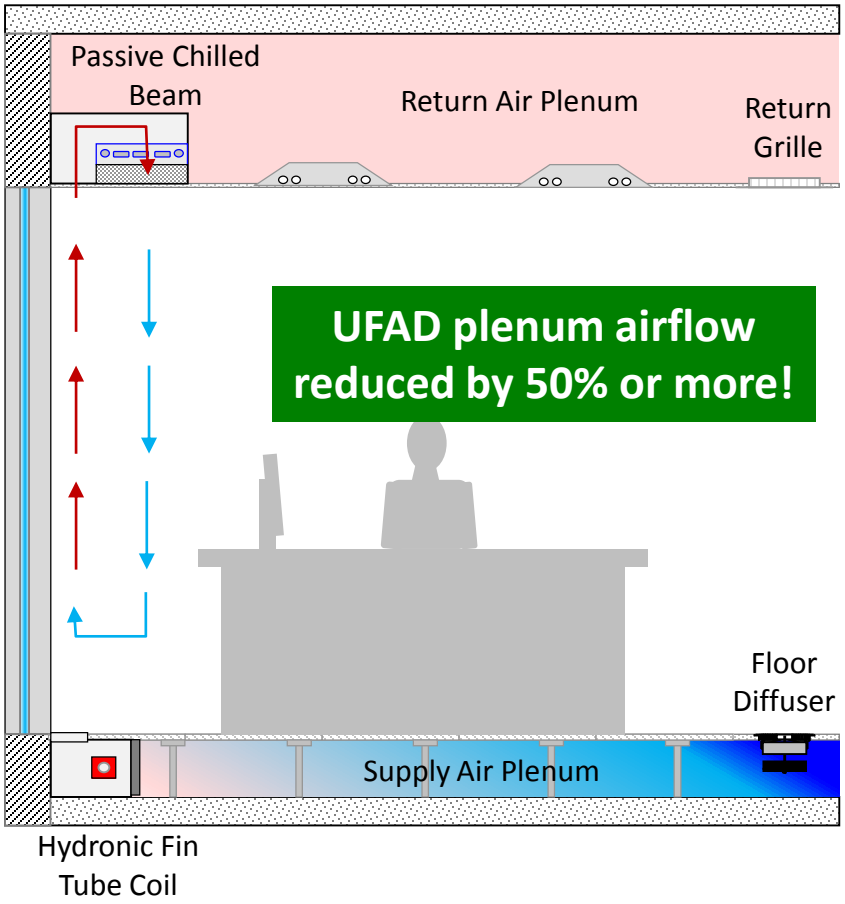


UFAD Plenum Heat Transfer

High supply air temperature → UFAD perimeter airflow rates as much as twice that of overhead systems



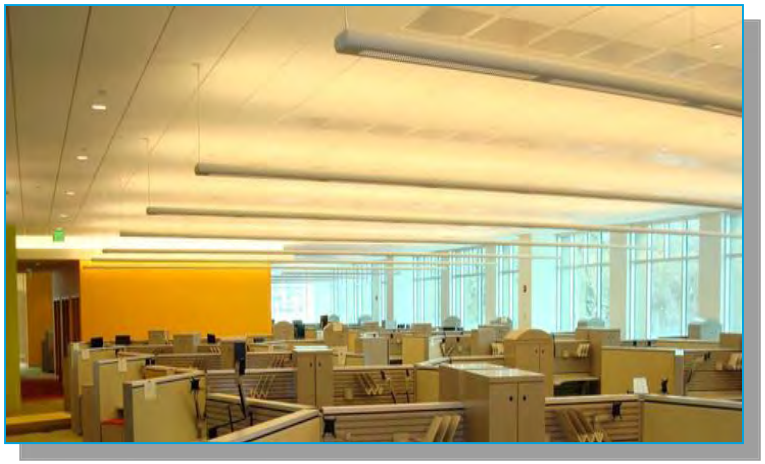
UFAD Perimeter Zone Treatment



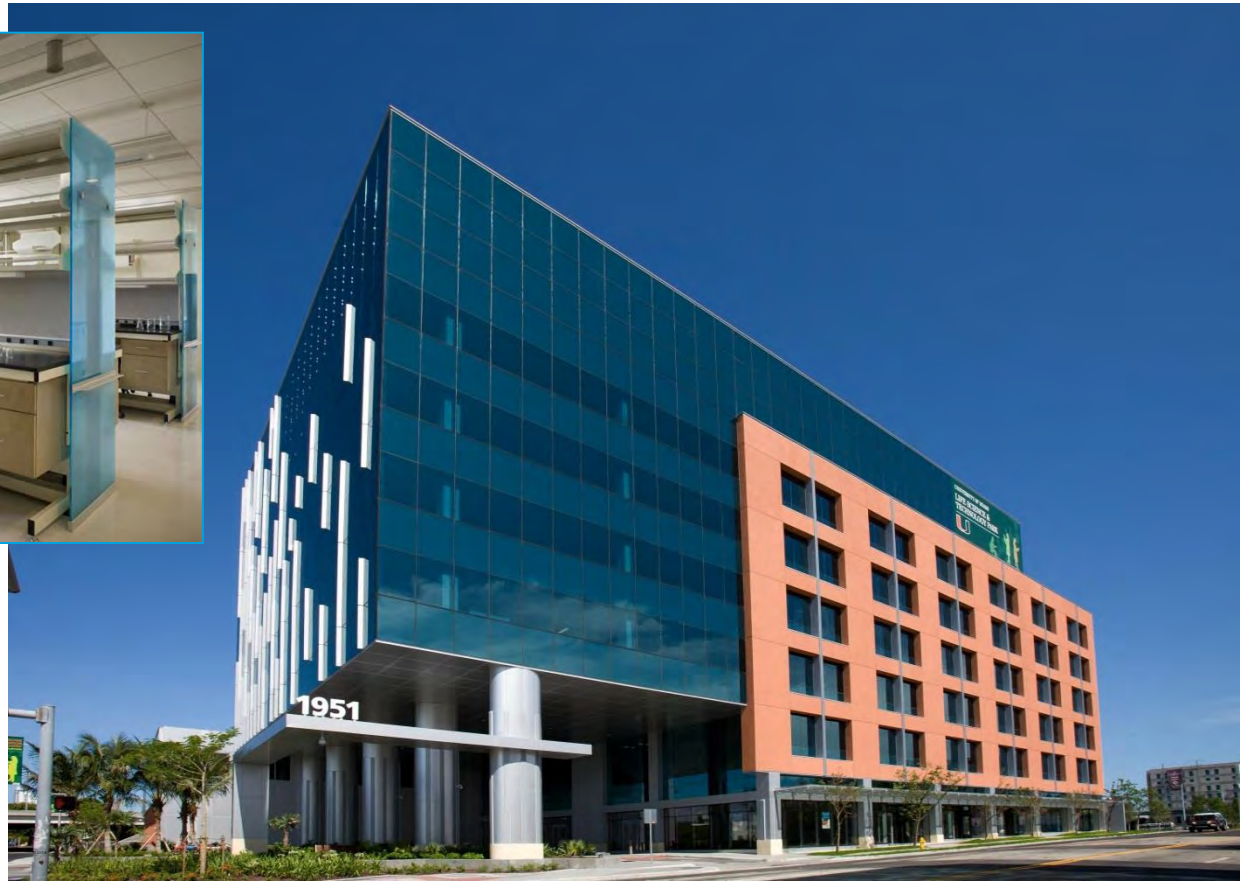
- Passive beam handles perimeter sensible load
- Diffusers responsible for ventilation and latent load
- Trench heating along perimeter wall

100 Howe Building

- Campuses in Covington, KY and Southlake, TX
- UFAD with passive chilled beams
- Two identical buildings in Covington with VAV systems
- UFAD system airflow reduced 60% by use of chilled beams
- First year 41% HVAC energy savings in new facility
- 2010 ASHRAE Technology Award winner



Active Beams for Laboratories



Laboratory Characteristics

- General
  - Strict ventilation requirements protect staff
  - Laboratories with chemicals and gases must exhaust all return air
- Laboratory classifications
  - Make-up air driven…. generally more than 10 ACH^{-1}
  - Heat driven (less than 10 ACH^{-1})
- Heat driven laboratories
  - Space sensible heat gains of 60 to 70 $BTUH/FT^2$
  - Space ventilation requirements typically 6 to 8 ACH^{-1}

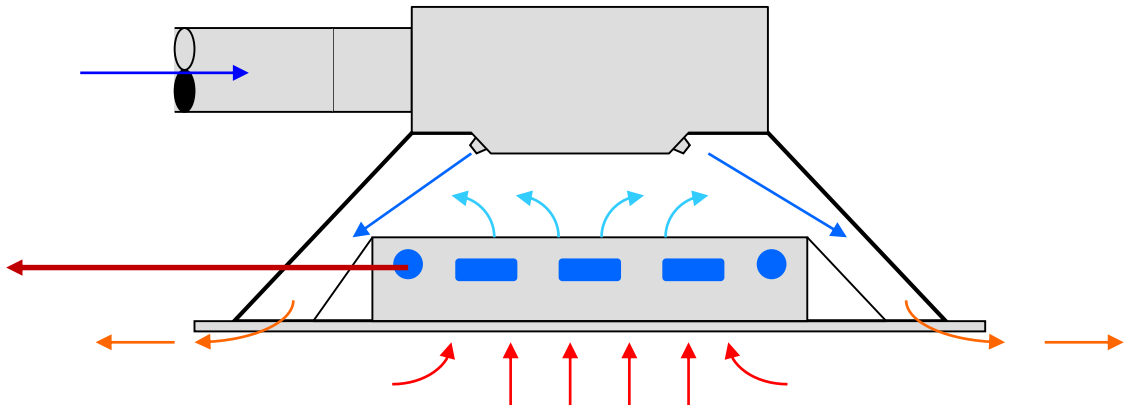
All air systems require 18 to 20 ACH^{-1} to satisfy laboratory sensible load

Active Beams for Laboratories

Three fold reduction in lab air change rate!

67% reduction in primary airflow

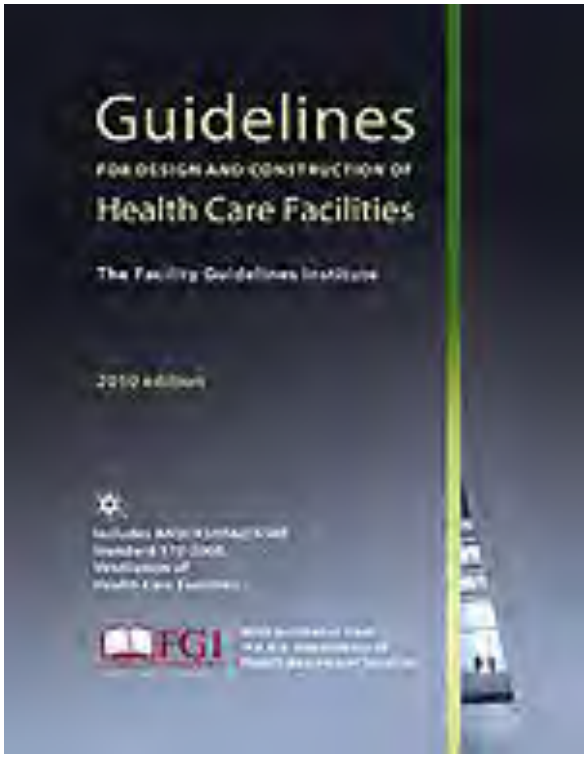
67% of space sensible heat removal by water



- *40 to 60% savings in air handling unit and chiller installed capacity*
- *25 to 50% savings in annual HVAC energy costs*

Active Beams for Healthcare

Patient Care Areas

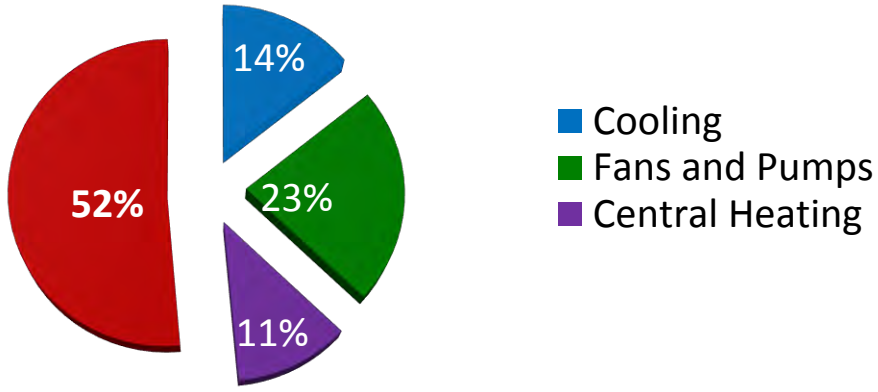


- Ventilation requirements
  - Minimum of 6 total ACH^{-1}
  - Minimum of 2 outdoor ACH^{-1}
- Room air recirculation not counted
- Filtration requirements
  - MERV 14 at AHU
  - MERV 6 within room

Hospital HVAC Energy Usage

Hospitals use 2.5 times the average of other commercial buildings on a per ft^2 basis!

Hospital HVAC Energy Usage Breakdown

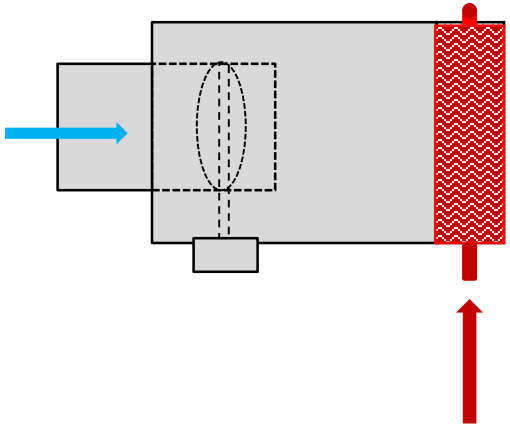


ASHRAE/DOE challenge to reduce hospital HVAC and lighting energy 30% by 2020

All Air VAV Systems

Primary Air

6 ACH^{-1} = 22 Btu/h-ft^2



20% of Design Load

5 Btu/h-ft^2

Reheat

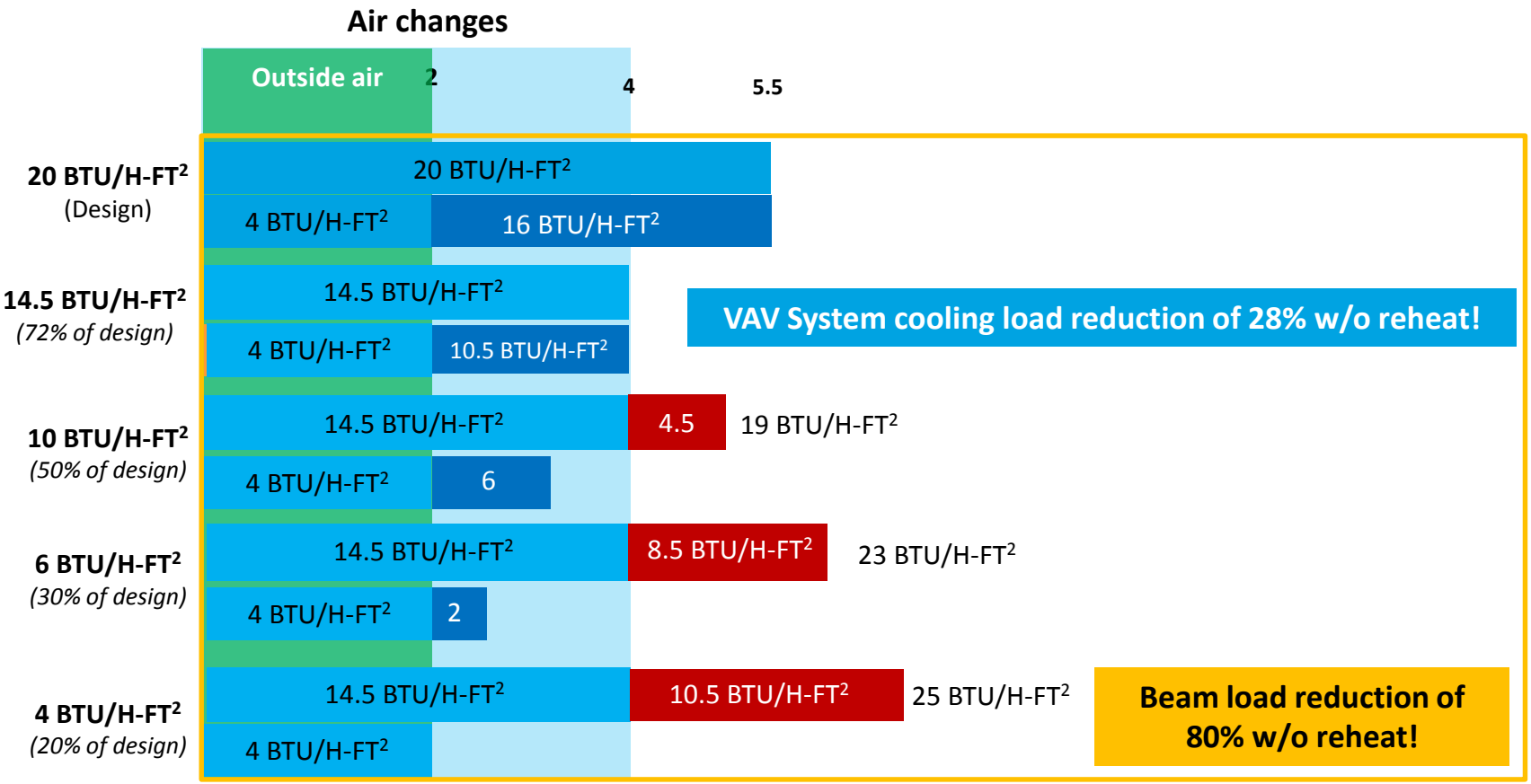
17 Btu/h-ft^2

ANSI/ASHRAE Std. 170-2013

- Total ACH^{-1} reduced from 6 to 4
  - Still requires 2 ACH^{-1} of outside air
  - Filtered (MERV 14) at the AHU
- Recirculation within same space counts toward the 2 non-outside air changes
- No room side filtration required if coils remain dry

Patient Suite HVAC Energy Use

Comparison of VAV system supplying at 55°F versus DOAS beam system supplying at 65°F



Moses Cone Hospital

- Greensboro, NC
- 270,000 ft^2, 96 acute patient beds, completed 2011
- Design team
  - Architect: Perkins & Will
  - MEP: AEI, Raleigh, NC
- Savings
  - Cooling energy 66%
  - Fan energy 27%
  - Reheat energy 88%

Presentation Seminar 50
2015 ASHRAE Winter Meeting,
Chicago, IL

Reference: Robert Sherman
Affiliated Engineers, Raleigh, NC
rhsherman@aeieng.com

Office Building Installations

Constitution Center

Washington, DC

National Geospatial Intelligence Agency

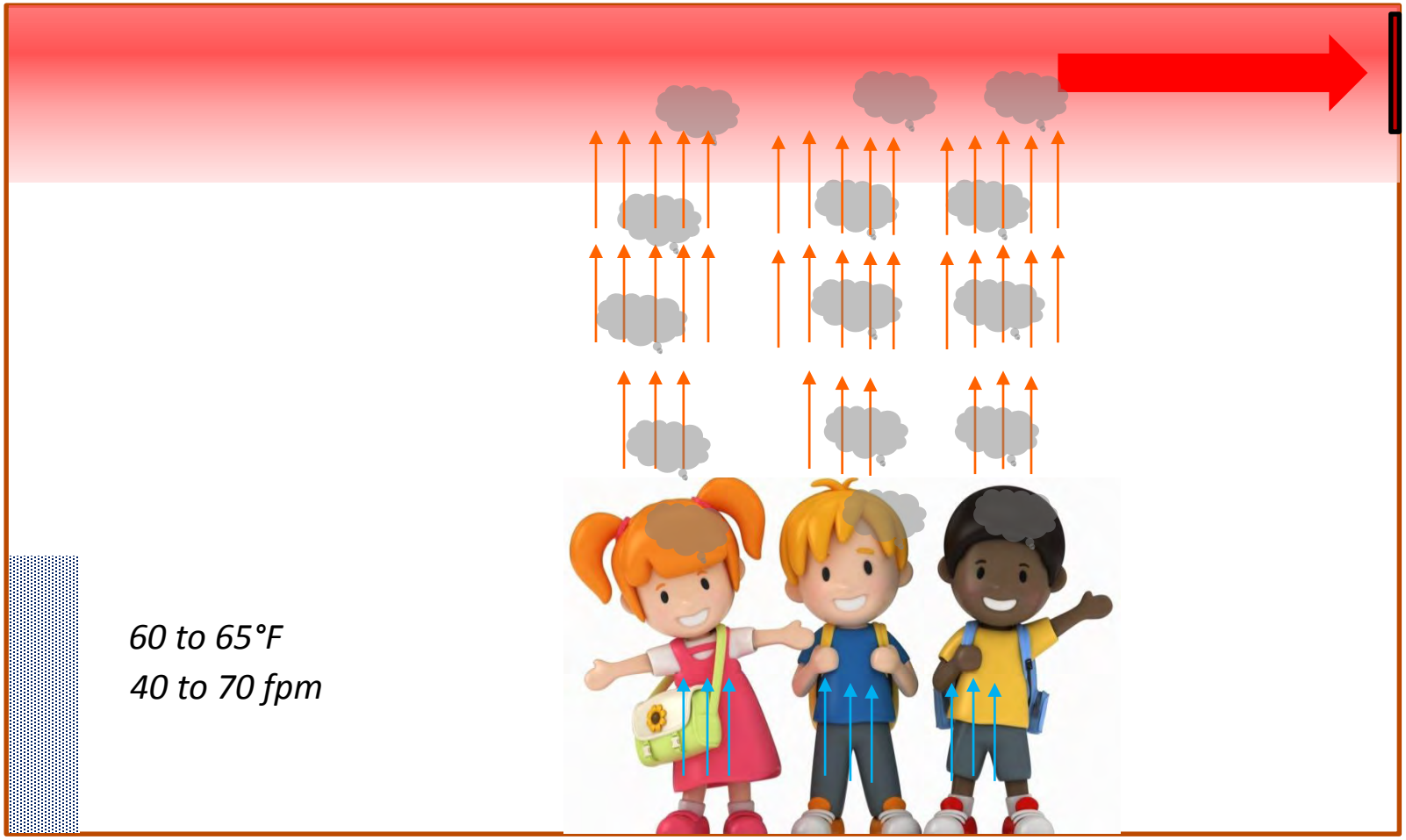
Fort Belvoir, VA

Educational Facilities

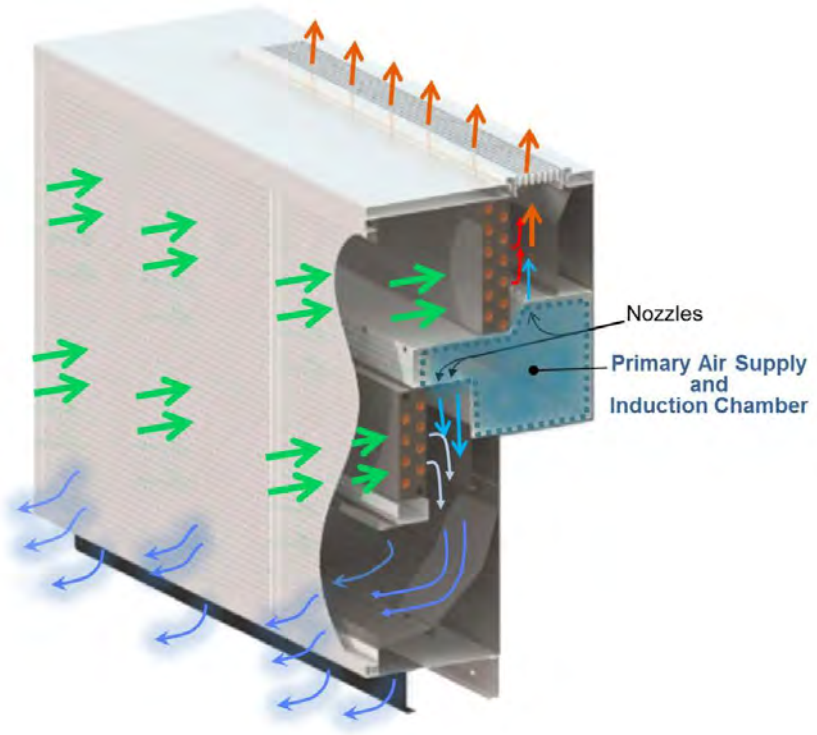
- Effective ventilation
- Improved acoustics

- Disease transmission
- Absenteeism
- Learning environment

Displacement Ventilation

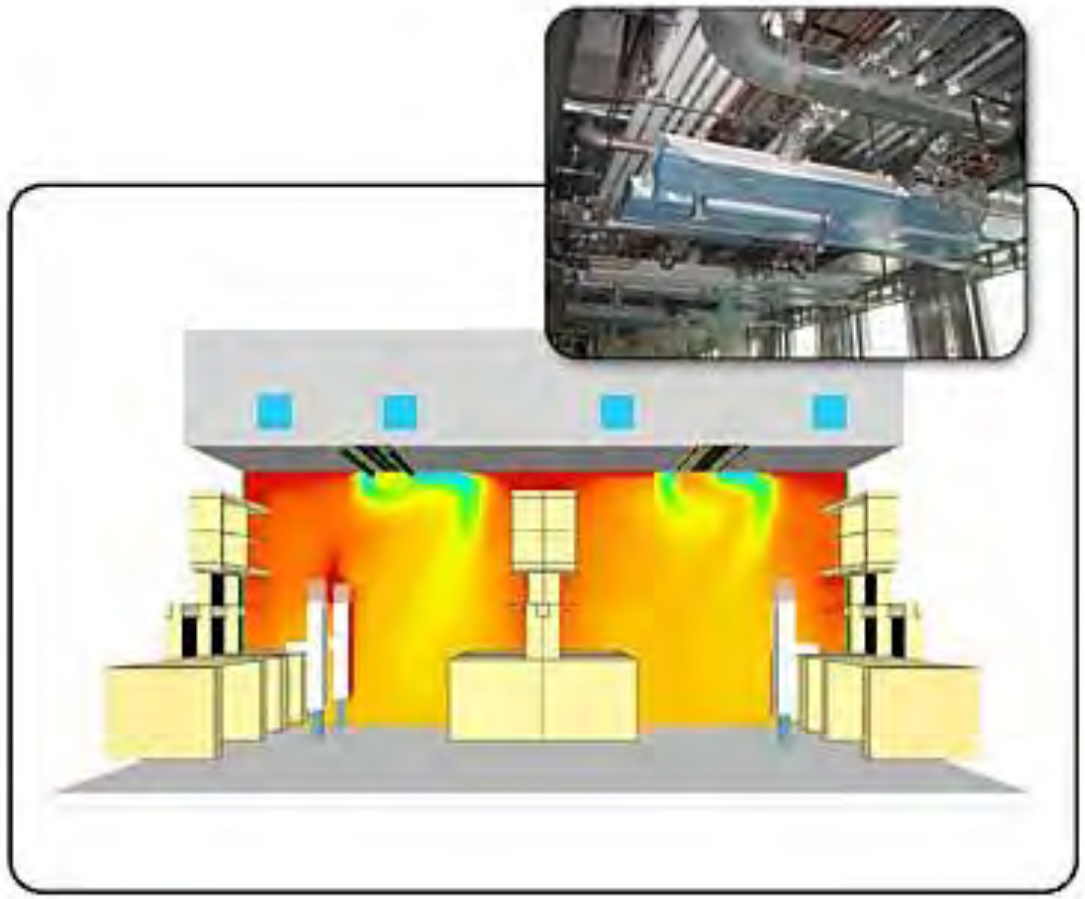


Displacement Chilled Beams



- Room side mixing simplifies AHU design especially in humid climates
- Separate coils allow for consistent ventilation effectiveness in both cooling and heating
- Vertical coil allows provision of gravity drain condensate tray
- Meets ANSI S12.60 requirements *(background noise level ≤ 35 dBA)*

Chilled Beam System Design



Air and Water Temperatures

- **Conventional system**

Discharge (supply) air, cooling	53-55°F
Discharge (supply) air, heating	90-95°F
Chilled water supply (to AHU)	40-45°F
Hot water supply	140 - 180°F

- **Chilled beam system**

Primary air (cooling)	53-65°F
Discharge (supply) air, cooling	61-70°F
Discharge (supply) air, heating	80-85°F
Chilled water supply	**55-62°F**
Hot water supply	**100-140°F**

Primary Airflow Rate

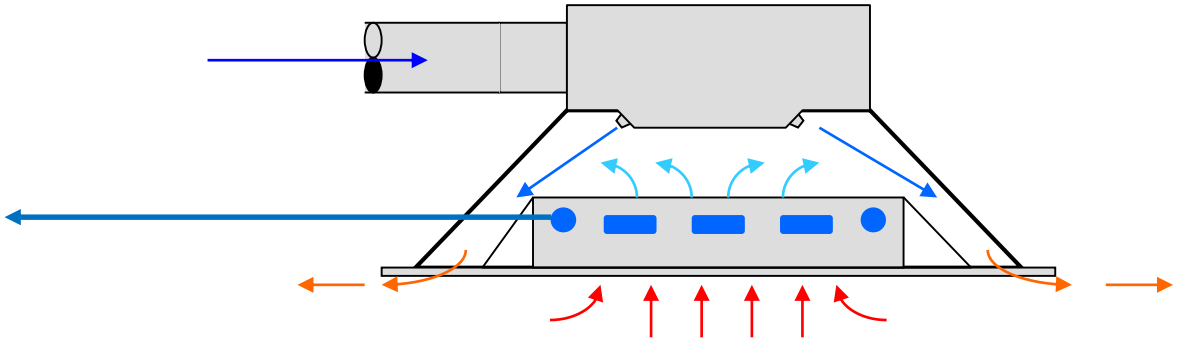
60 to 80% reduction in space latent cooling

↑

60 to 80% reduction in primary airflow

↑

60 to 80% of space sensible heat removal by water

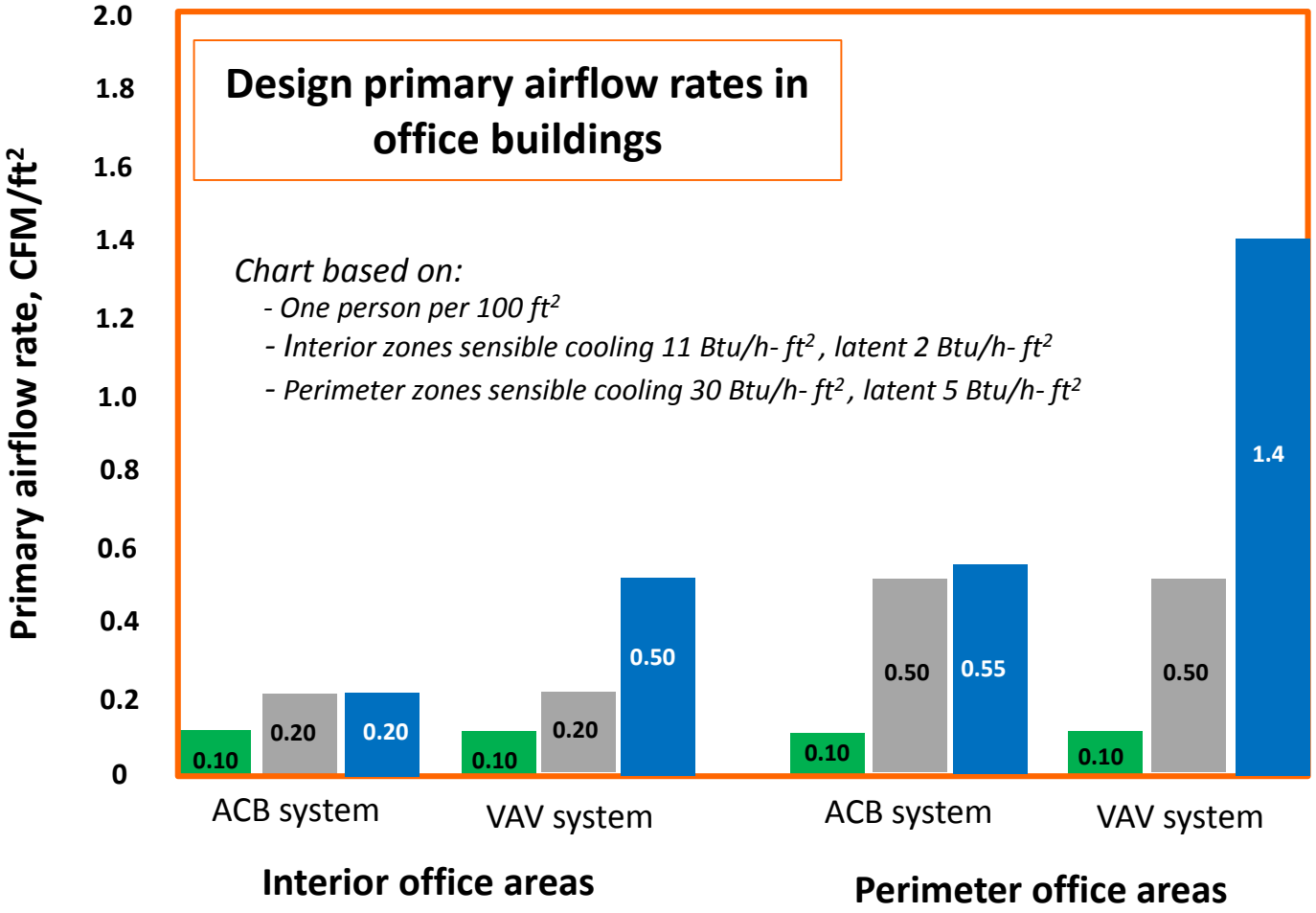


Beam's primary airflow rate is the greatest of the following:

- Primary airflow rate required for space ventilation
- Primary airflow rate required for the necessary space latent heat removal
- Primary airflow rate required to drive the space sensible cooling
  - *Direct contribution by cool primary air introduced into the space*
  - *Plenum pressurization to adequately drive the beam induction process*

Ideal scenario occurs when <u>all three functions</u> require same primary airflow rate!

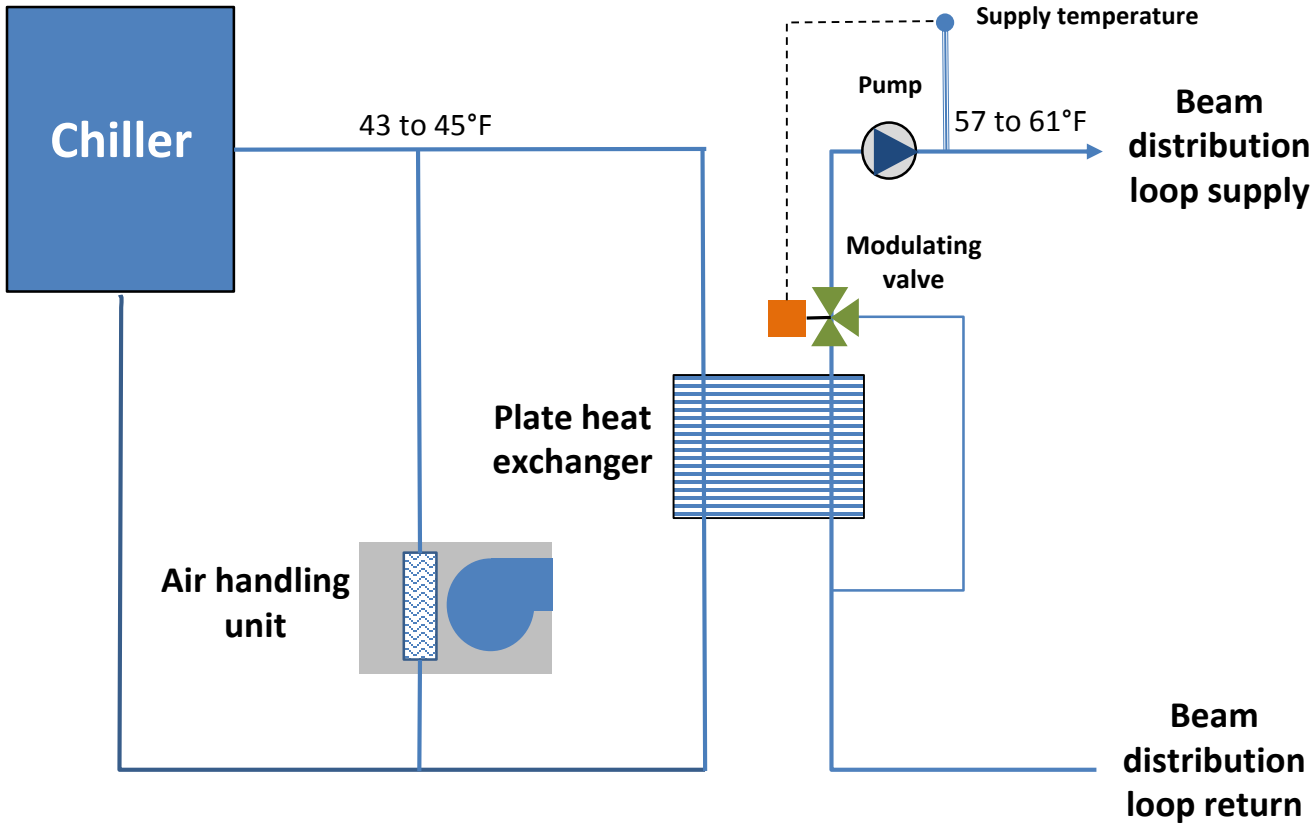
Primary Airflow Rates



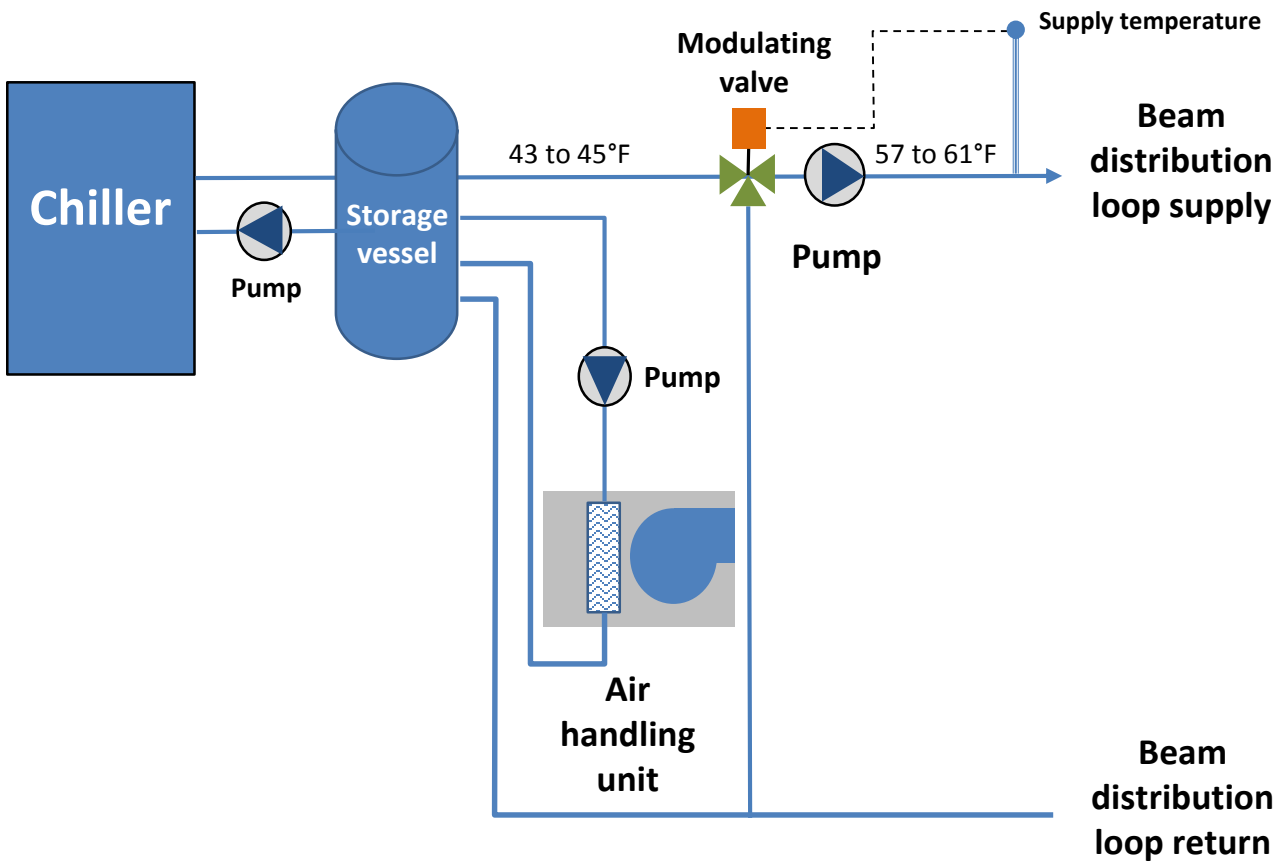
Water Side Design

- Chilled water source
- Piping and zoning
- Condensation

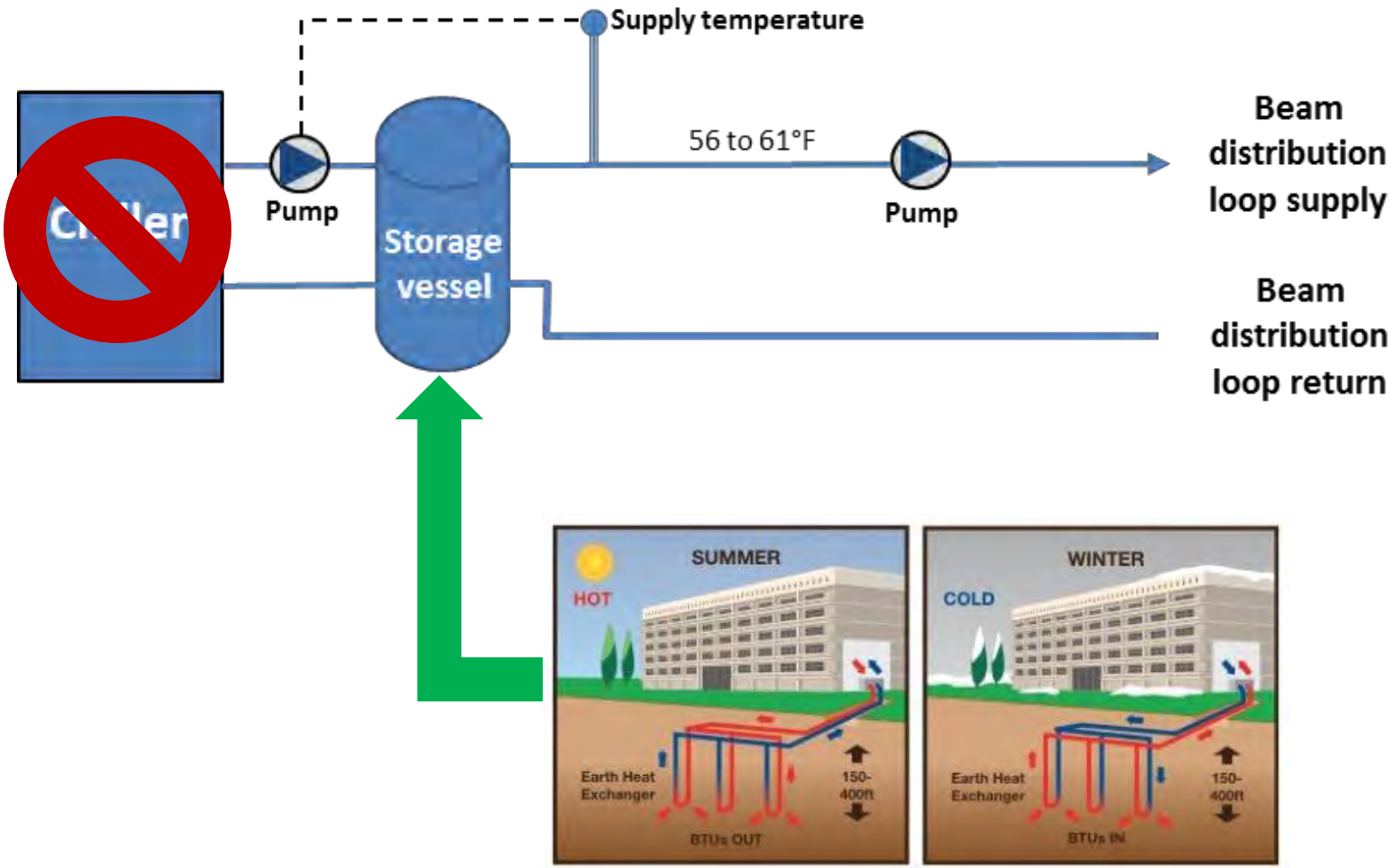
Closed Loop Beam Supply



Open Loop Beam Supply



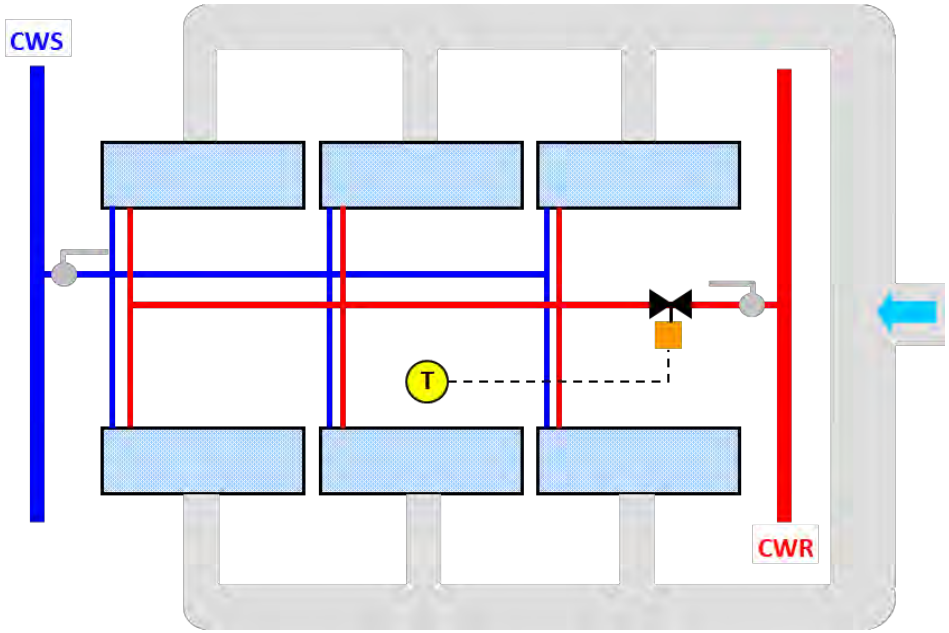
Dedicated Chilled Water Source



Water Distribution Strategies

Zoning similar to all air system!

2 pipe water distribution system

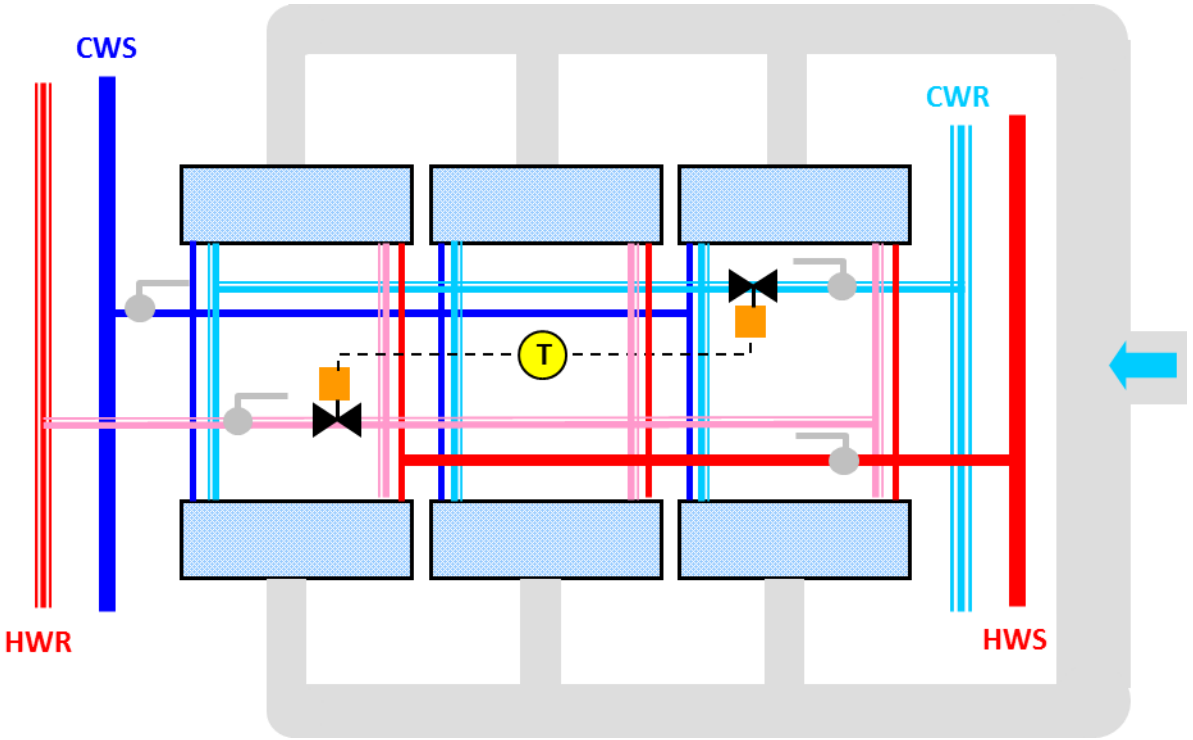


Commonly used where beams are not required to provide heat

Not recommended when simultaneous cooling and heating is required

Water Distribution Strategies

4 pipe water distribution system



Commonly used where beams are also used for heating

Condensation Formation

Chilled water supply temperature = 58°F

VRF Systems

- Refrigerant issues
  - High pressure piping (500 psi)
  - Leakage potential
  - Replacement and reclaim every two years
  - Likely refrigerant change outs over building life
- Application issues
  - Not suitable for high rise buildings
  - Not suitable for open office plans
  - Little or no room air distribution data
- Operation and maintenance
  - Filter changes every 3 to 4 months
  - Condensate removal
- Economic issues
  - Proprietary system, limited bidders
  - High component cost and repair costs
  - Questionable energy performance

Chilled Beam Alternative

- Refrigerant issues
  - Water is the primary cooling media
  - Any refrigerant issue is contained in the mechanical room
- Application issues
  - Suitable for any building type and size where chilled water can be justified
  - Can be used with geothermal heat sinks
  - Documented air distribution performance
- Operation and maintenance
  - No condensation within the space
  - No filters required
  - Vacuum coil every five years
- Economic issues
  - Many suppliers, comparable performance
  - No moving parts on beam, simple control system
  - Proven energy performance

Chilled Beams and the 2016 WSEC

Chilled beam systems compliance

- Ventilation (C403.2.6)
  - ACB with DOAS complies with maximum ventilation air restriction
  - ERV (C403.5.1) not required for DOAS units serving less than 30,000 ft^2
- DOAS for ventilation air (C403.6)
  - Cooling/heating supplemented at zone level
  - 60 to 80% of space sensible heat removal is water borne, increases number of hours where OA can be delivered without mechanical cooling or heating
  - Significant reduction in space reheat energy
- Economizers (C403.3)
  - Prescriptive in language
  - Exceptions
    - Systems complying with section C403.6 (DOAS)
    - Water cooled refrigeration equipment utilizing cooling towers
    - VRF and (?) fan coil systems
  - Air side economizer not required due to DOAS exception
  - If water side is required, what about any other systems utilizing a chiller

Questions?

Titus
Redefine your comfort zone.™