ACTIVE CHILLED BEAM SYSTEMS

ASHRAE Chapter NB/PEI October 2011

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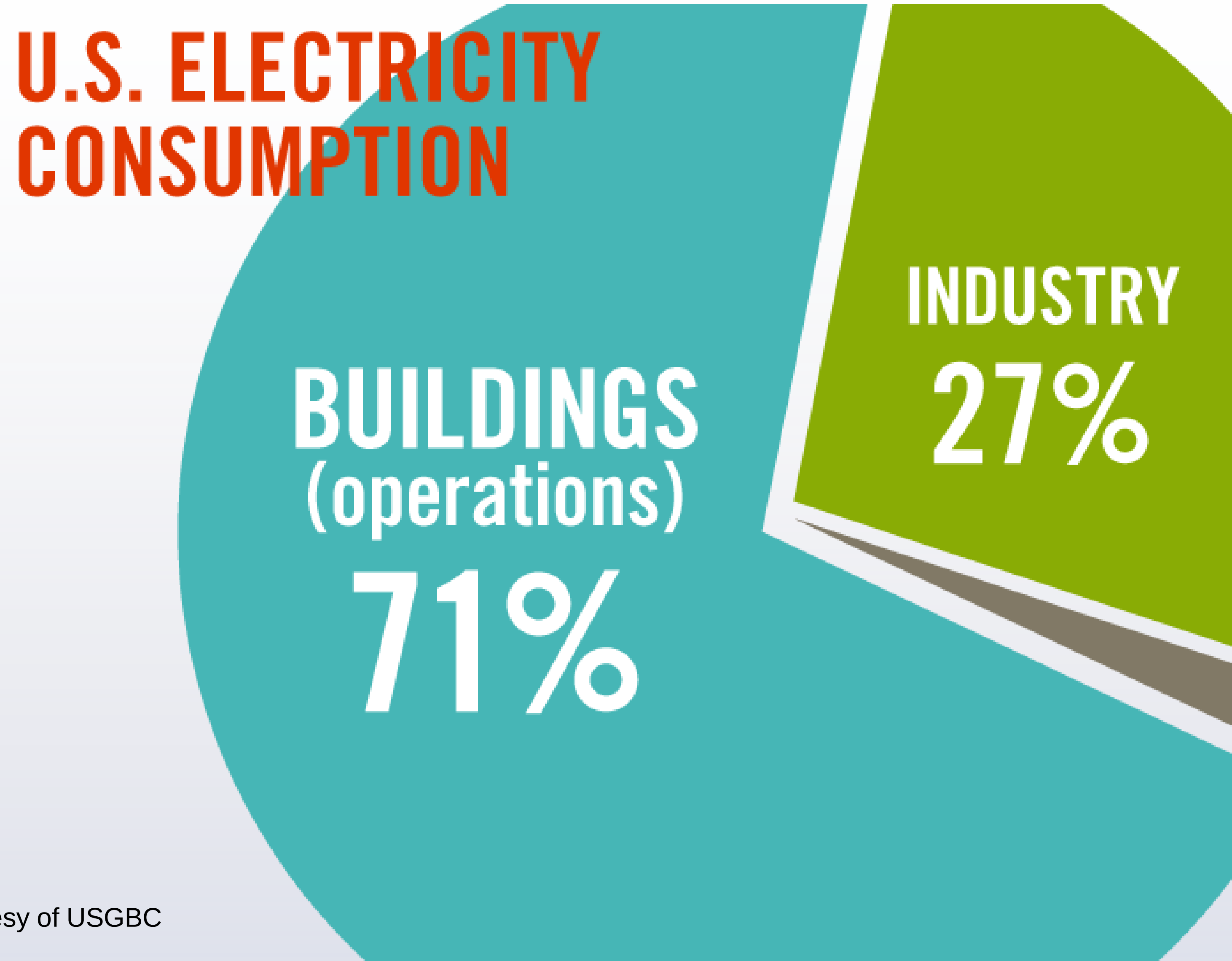
Agenda

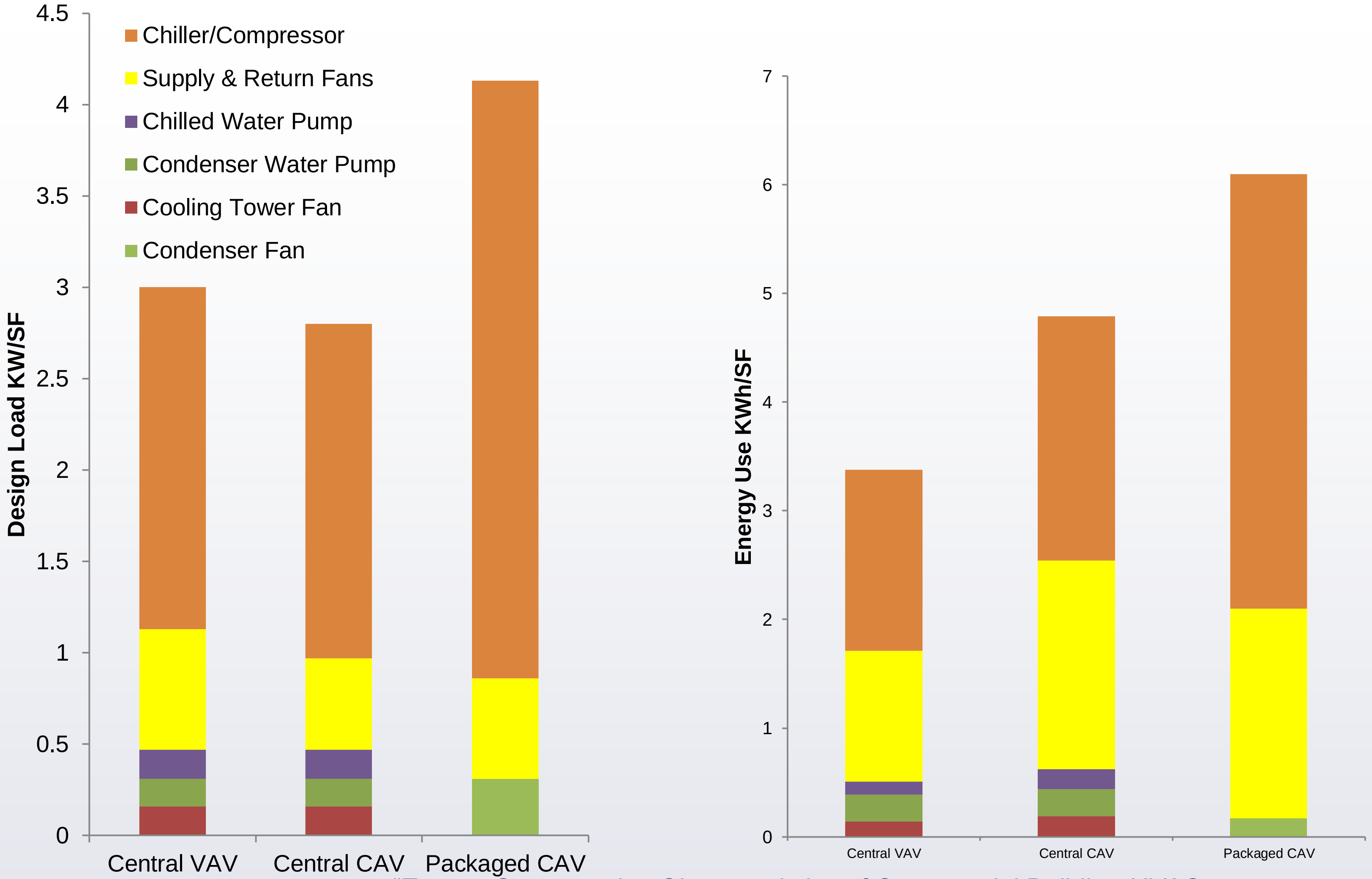
- Chilled Ceilings and Beams –
  The Different Types of Chilled Beams
- Going Green with Active Chilled Beams
- Active Chilled Beams
  - Benefits
  - Application Considerations
  - System Design
  - Cost Considerations
- Case Study
- Product Models

U.S. Energy Consumption

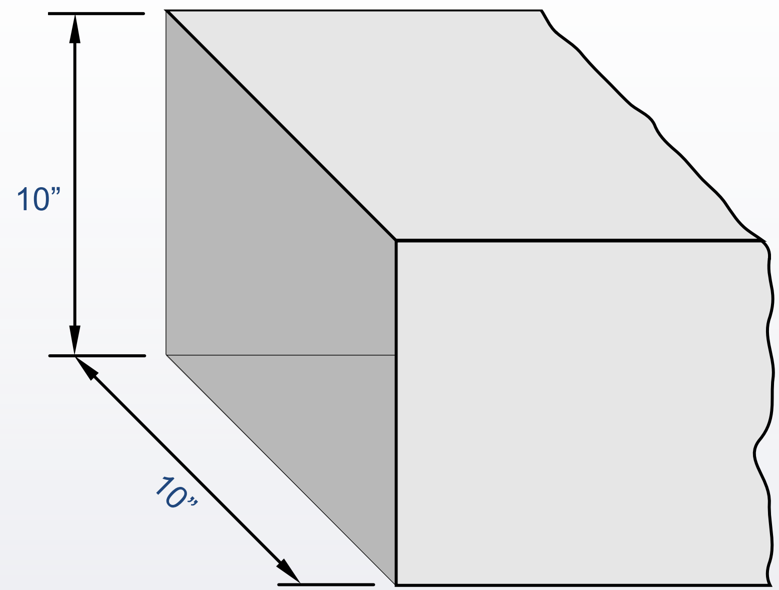


Courtesy of USGBC

Fan Energy Use in Buildings



"Energy Consumption Characteristics of Commercial Building HVAC Systems" - publication prepared for U.S. Department of Energy



1 Ton of Cooling

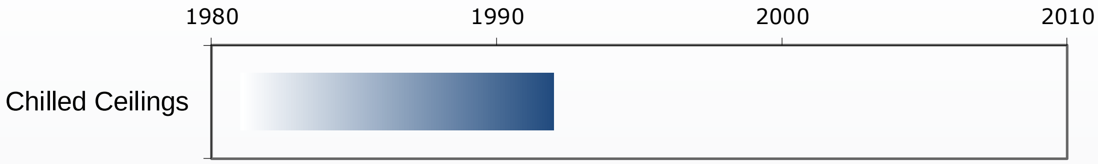
requires 550 CFM of air

or

4 GPM of water

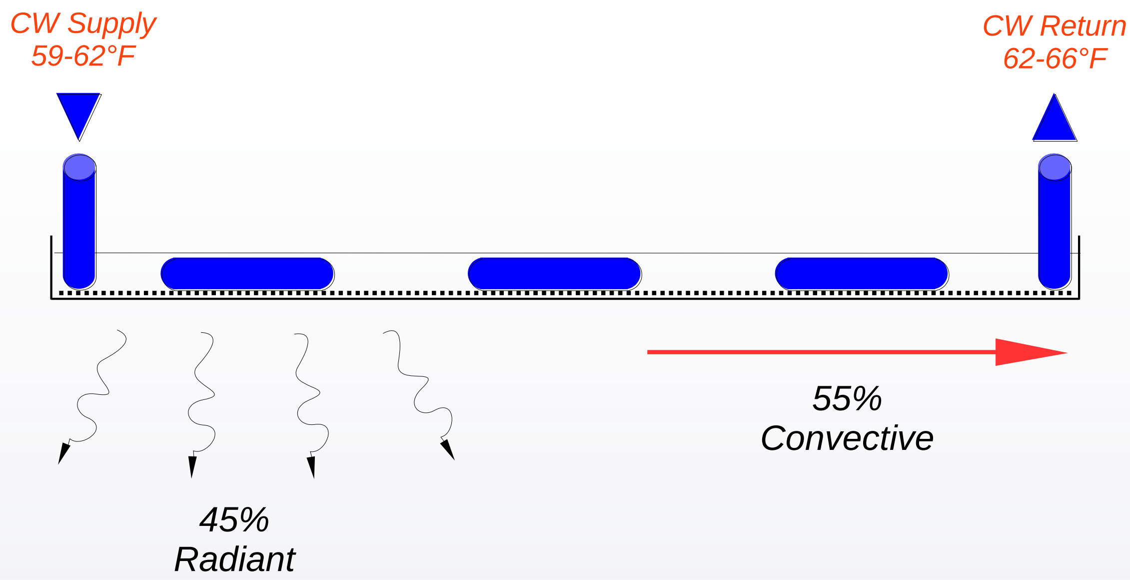
¾” diameter
water pipe

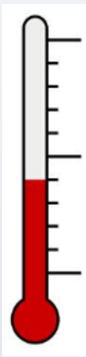
Chilled Ceilings



- Many buildings heated only
- PC's appearing on desks
- Restricted ceiling cavity

Chilled Ceilings Radiant Effect





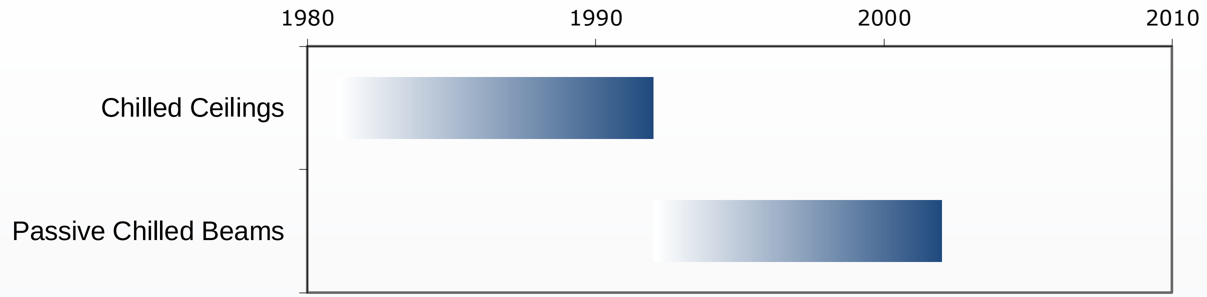
Advantages

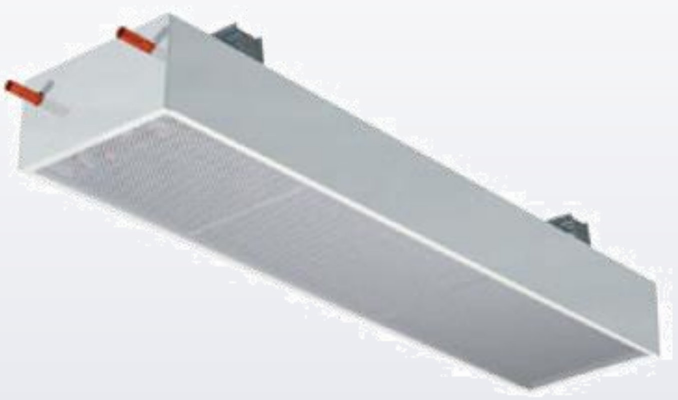
- Excellent thermal comfort
- Reduced space requirement
  - Will fit into 6-8” cavity
- Self regulating
  - Simple controls
- Low noise
- Low maintenance

Design Issues

- Low cooling output
  - 20 to 25 BTUH/FT2
    100% coverage
  - 14 to 18 BTUH/FT2
    70% coverage
- High cost
- Separate air system required

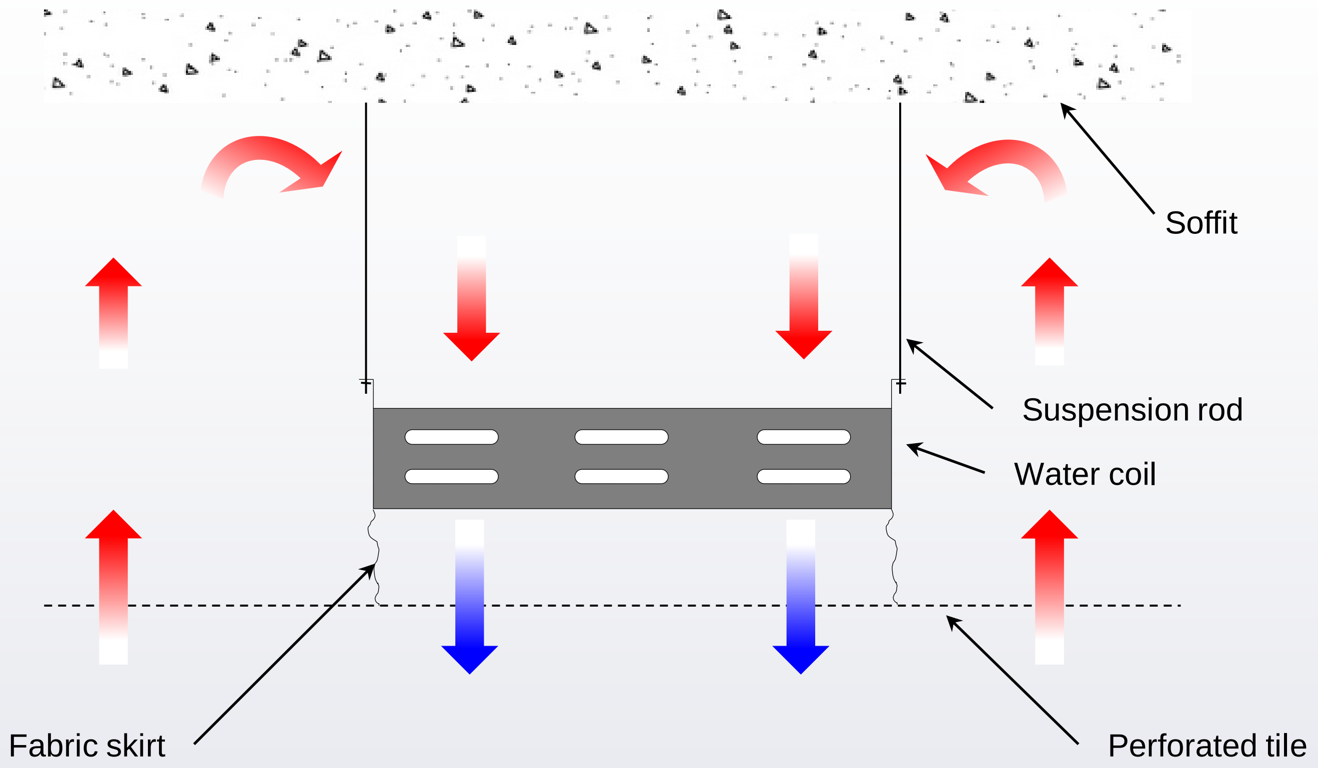
Passive Chilled Beams





- Increased cooling loads
  - Equipment
  - Occupancy
  - Day-lighting
- Inadequate perimeter cooling

Passive Chilled Beam Operation Principle

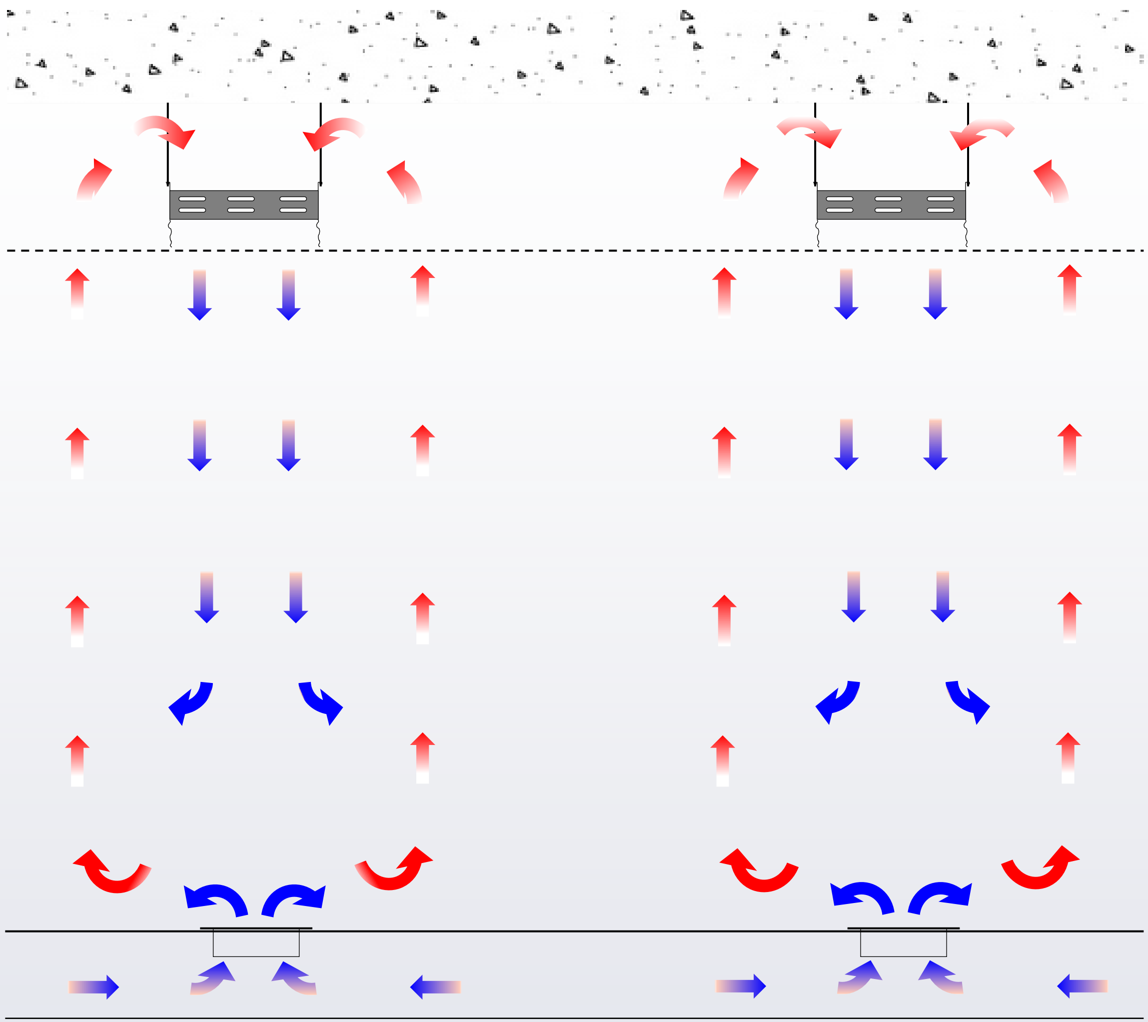


Passive Chilled Beam Benefits

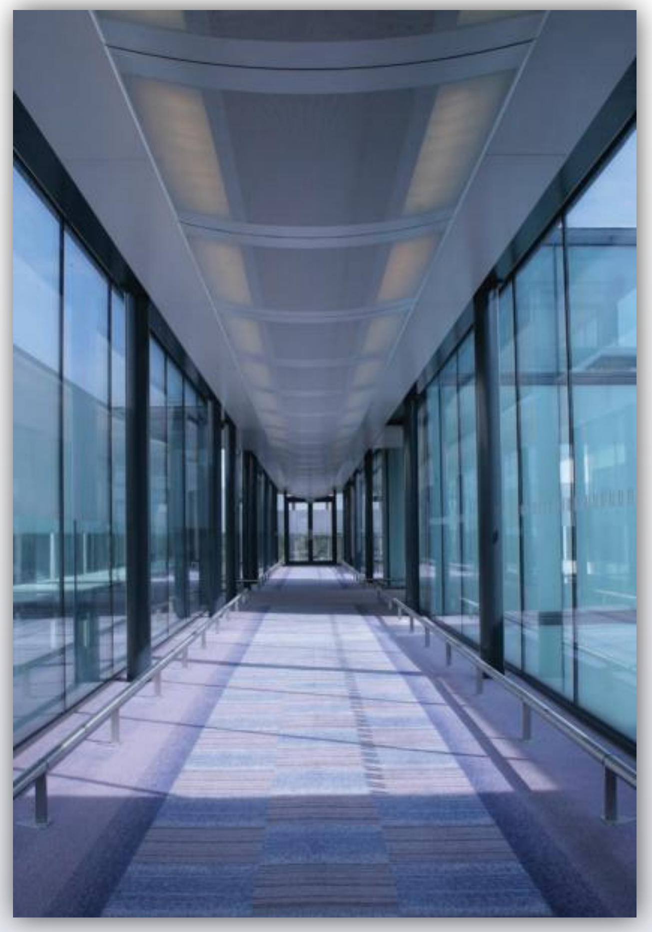
- Good thermal comfort
- Cooling capacity up to 40 BTUH/FT2 floor space
    - Up to 400 BTUH per LF of beam
- Reduced ductwork, riser and plant sizes
    - Water transports most of sensible cooling
- Self regulating
    - Simple two position controls
- Low noise
- Low maintenance

- Sensible cooling only
  - Latent gains must be controlled by air system
- High free area perforated metal ceiling required
  - 28% free area minimum
  - Exposed beams (no ceiling) are an option
- Beams cannot be installed tight against slab
  - Typically 40% of beam width required above beam
- Separate heating system must be installed

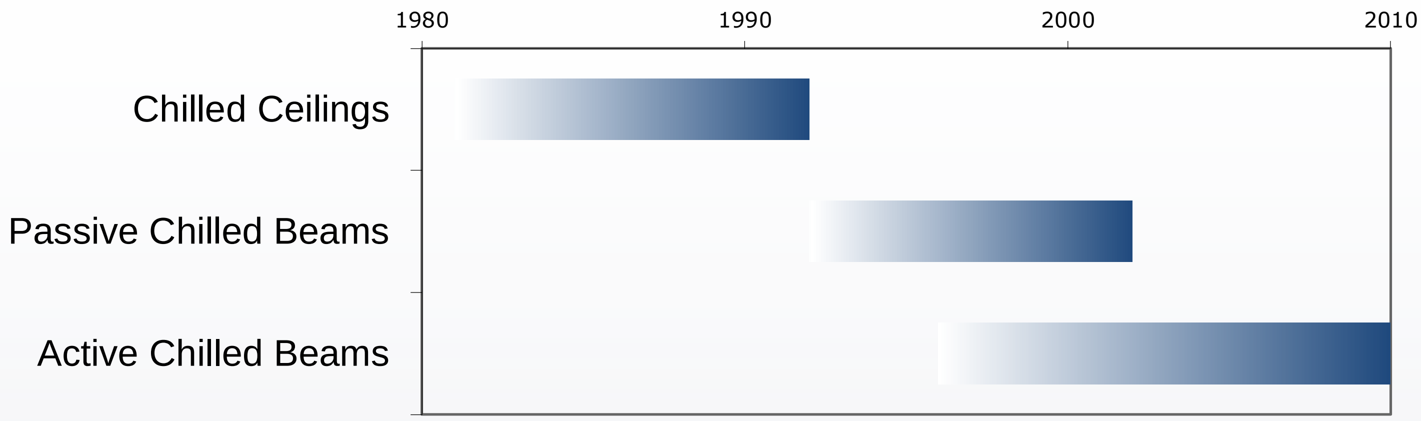
Passive Chilled Beam Airflow



Recessed Passive Beams

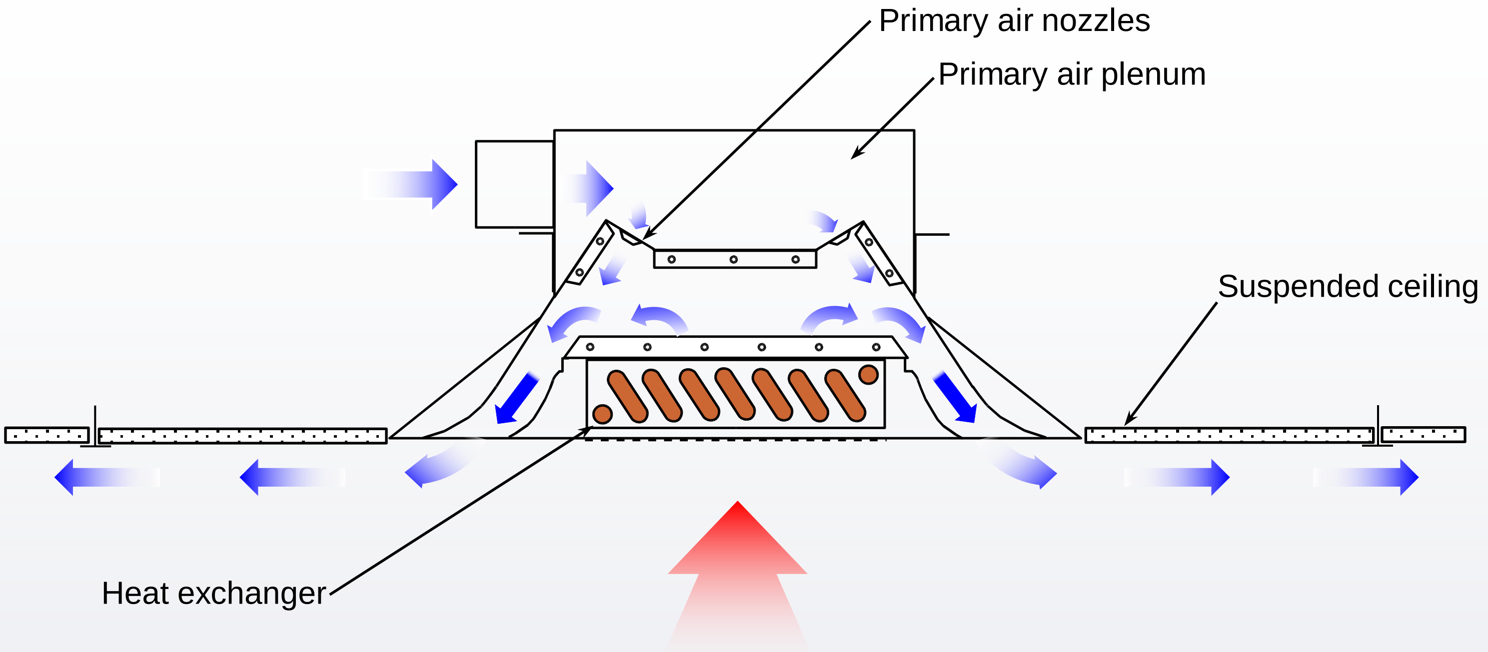


Exposed Passive Beams

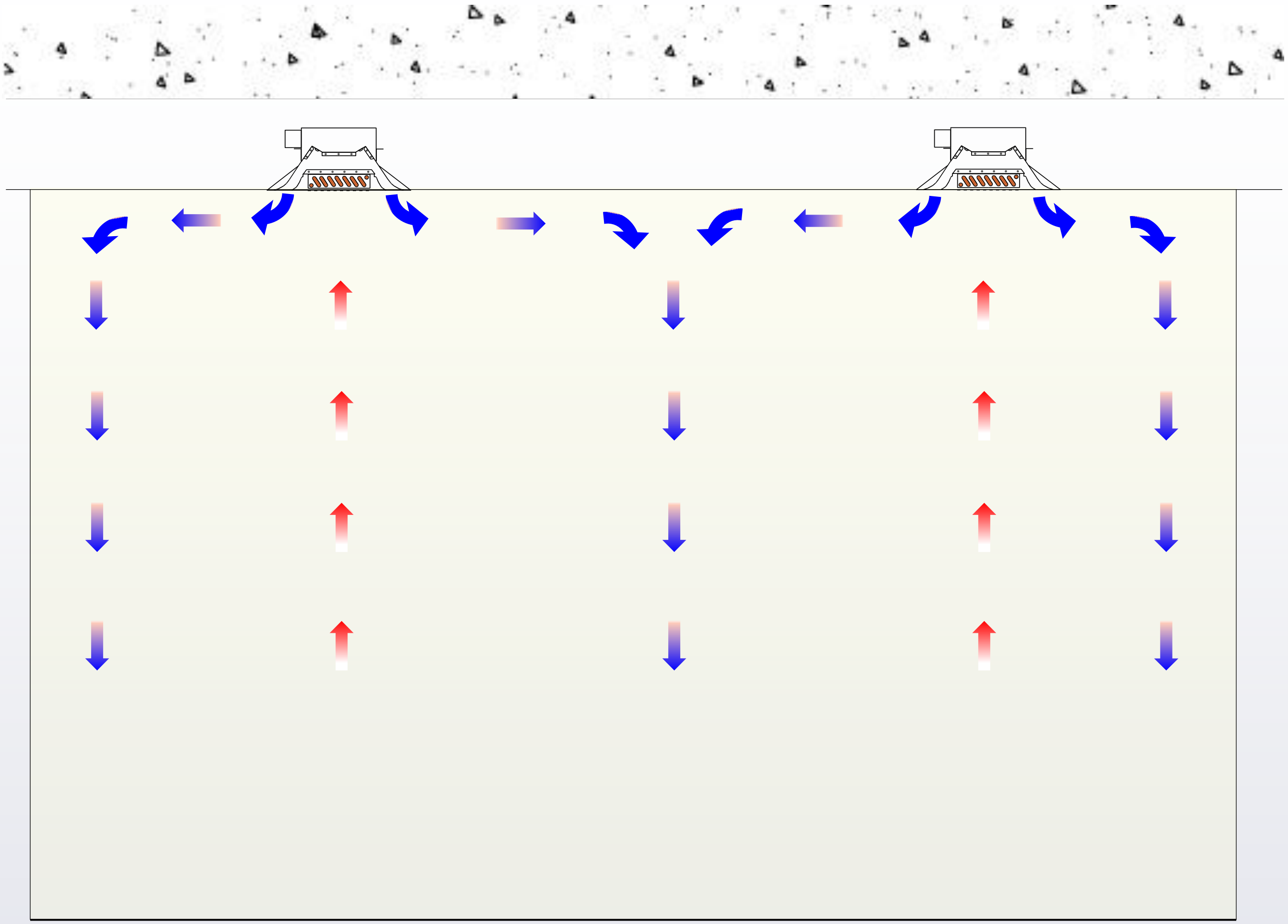


- Higher space loads
- Higher occupant densities
- Combined ventilation/cooling preferred
- Integration into fiber tile ceilings required

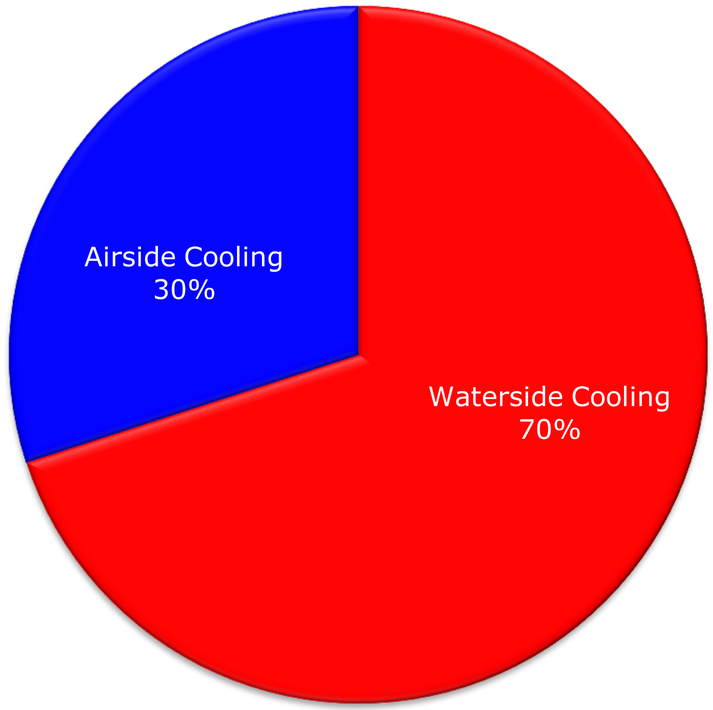
Active Chilled Beam Operation Principle



Active Chilled Beam Airflow Pattern



Heat Removal Ratio



Active Chilled Beam Summary of Benefits

- Very high cooling capacity
  - Up to 100 BTUH/FT2 floor space
  - Up to 2000 BTUH per LF
- Integrated cooling, ventilation and heating
  - All services in the ceiling cavity
- Suitable for integration into all ceiling types
  - Reduces ceiling costs compared to Passive Beams

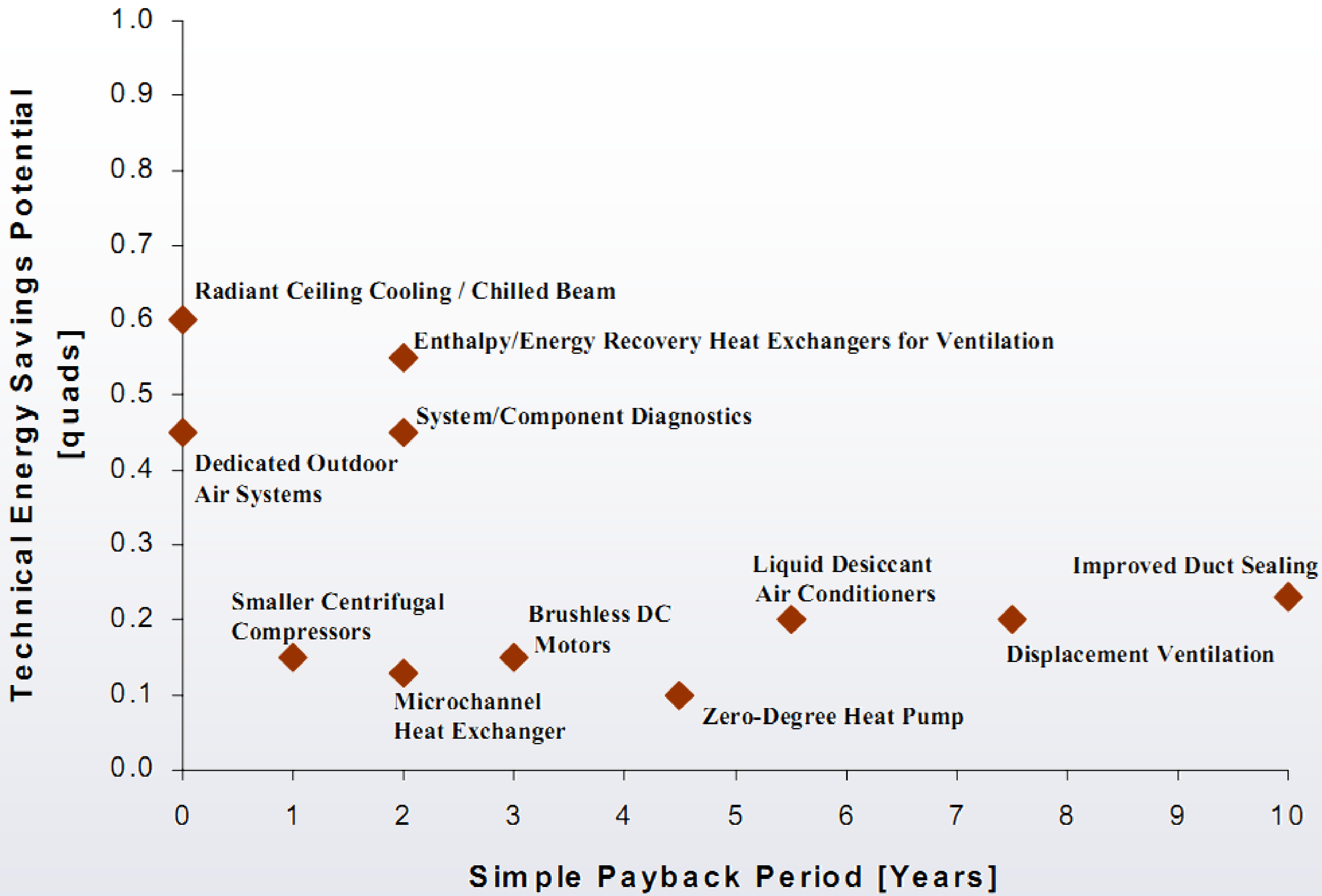
Active Chilled Beam Summary of Benefits

- Significant space savings
  - Smaller ductwork saves space in shafts, plant rooms and ceiling
- Can be installed tight up against the slab
  - Reduced floor to floor heights
  - Reduced construction costs on new buildings
- Low noise levels
- Low maintenance
  - No moving or consumable parts

Energy Savings Compared to VAV

Source	Technology	Application	% Saving*
US Dept. of Energy Report (4/2001)	Beams/Radiant Ceilings	General	25-30
ASHRAE 2010 Technology Awards	Passive Chilled Beams	Call Center	41
ACEE Emerging Technologies Report (2009)	Active Chilled Beams	General	20
ASHRAE Journal 2007	Active Chilled Beams	Laboratory	57
SmithGroup	Active Chilled Beams	Offices	24
*Compared to VAV			

First Cost Compared to VAV



"Energy Consumption Characteristics of Commercial Building HVAC Systems" - publication prepared for U.S. Department of Energy

LEED Certification

- Optimize Energy Performance

  - up to 48% (new) or 44% (existing)more efficient than

  ASHRAE 90.1

  (EA Credit 1) - up to 19 points

- Increased Ventilation

  - 30% more outdoor air than

  ASHRAE 62

  (IEQ Credit 2) - 1 point

- Controllability of Systems

  - individual temperature control

  (IEQ Credit 6.2) - 1 point

- Thermal Comfort

  - meet ASHRAE 55

  (IEQ Credit 7.1) - 1 point

(Minimum 40 points needed for certification out of 100 maximum)

- No moving parts
- No filter
- No condensate pumps
- No consumable parts
- Up to 4 year inspection & clean
- Easy maintenance access

Active Chilled Beams
Typical Installation

ACTIVE CHILLED BEAM DESIGN CONSIDERATIONS

Building Characteristics that *favor* Active Chilled Beams

- Zones with moderate-high sensible load densities
  - Where primary airflows would be significantly higher than needed for ventilation
- Buildings most affected by space constraints
  - Hi – rises, existing buildings with induction systems
- Zones where the acoustical environment is a key design criterion
- Laboratories where sensible loads are driving airflows as opposed to air change rates
- Buildings seeking LEED or Green Globes certification

Characteristics that *less favor* Active Chilled Beams

- Buildings with operable windows or “leaky” construction
  - Beams with drain pans could be considered
- Zones with relatively low sensible load densities
- Zones with relatively low sensible heat ratios and low ventilation air requirements
- Zones with high filtration requirements for the re-circulated room air
- Zone with high latent loads

Required Design Data

- Room Design Conditions
- Room Sensible Cooling Loads
- Room Latent Cooling Loads
- Room Heating Loads (if used for heating)
- Infiltration Loads
- Minimum Outside Air Quantity per Zone
- Secondary Chilled Water Conditions and Flow
- Primary Air Conditions and Inlet Pressure
- Desired Room Air Change Rate (if required)
- Spatial Considerations/Constraints
- Room layout/Drawings
- Unit models desired

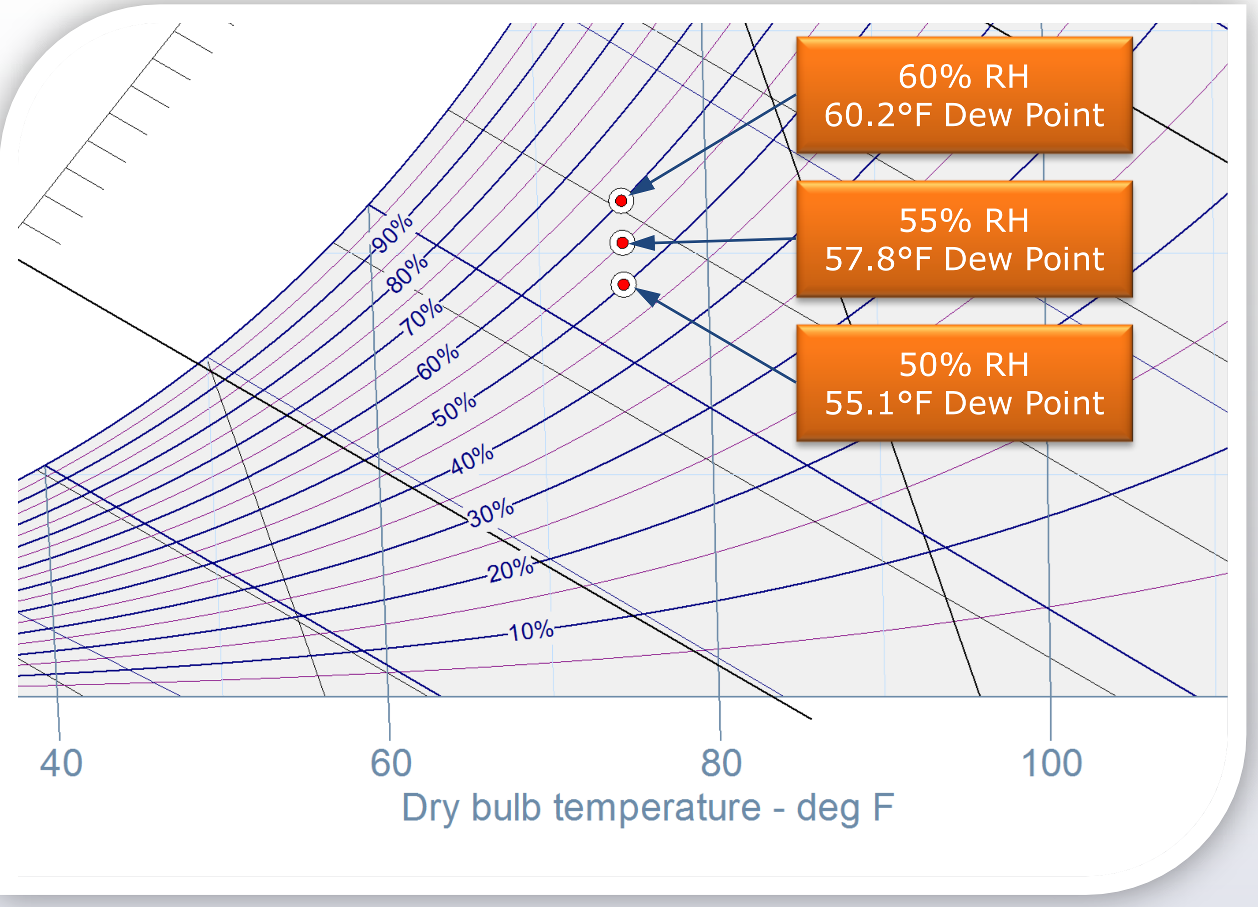
- Ventilate the occupants according to ASHRAE 62
- Handle all of the latent load in the space
  - Primary air is only source of latent heat removal
- Create induction through chilled beam
- Pressurize the building

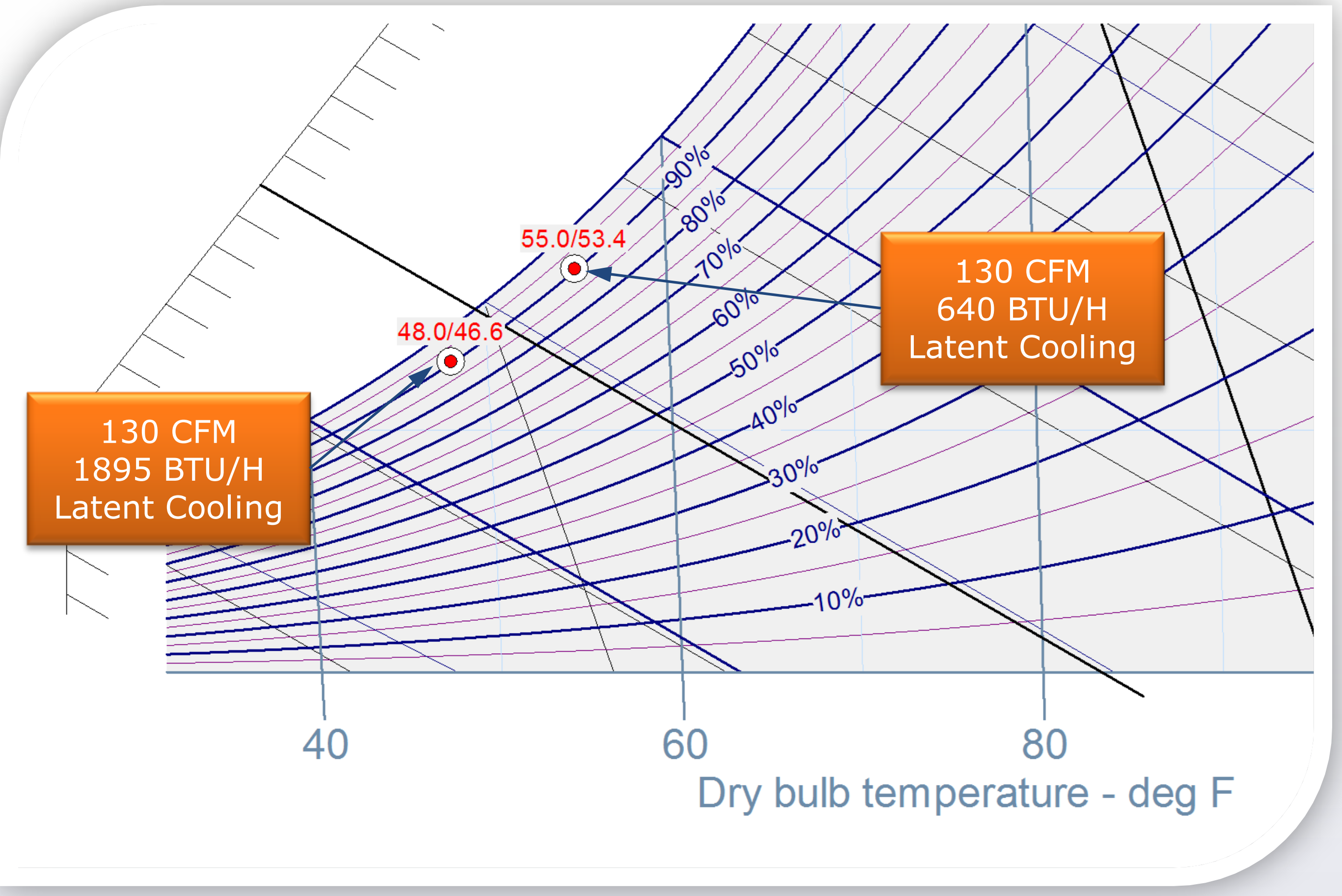
- Central AHU sized to handle:
  - sensible and latent cooling/heating of the ventilation air
  - portion of the sensible internal cooling/heating loads

AND

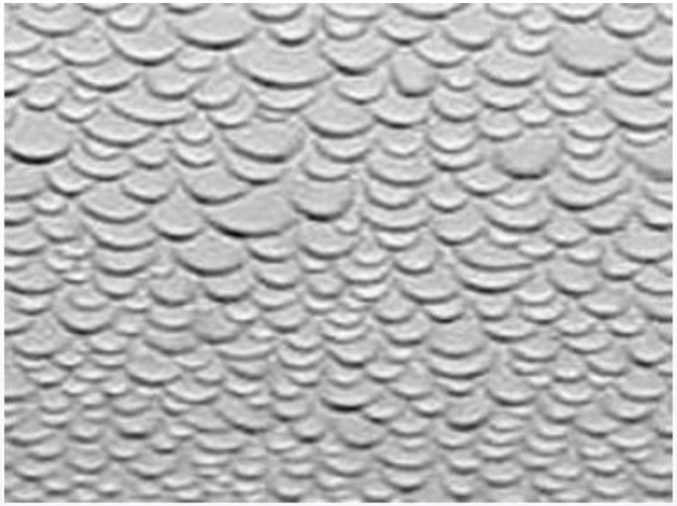
  - all of the internal and infiltration latent loads
- Primary air delivered continuously to the chilled beams
  - VAV primary air can be considered for the perimeter if the sensible loads are high
- Chilled beam water coils provide additional sensible cooling/heating to control zones

Why is it important to satisfy the latent load in all sensible load conditions?



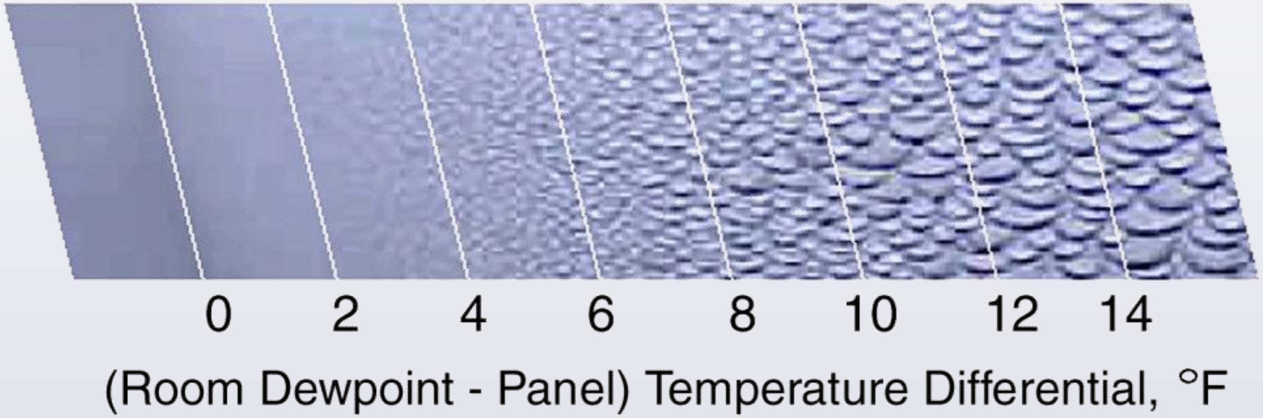


55.0/53.4
48.0/46.6
90%
80%
70%
60%
50%
40%
30%
20%
10%
130 CFM
640 BTU/H
Latent Cooling
130 CFM
1895 BTU/H
Latent Cooling
40
60
80
Dry bulb temperature - deg F



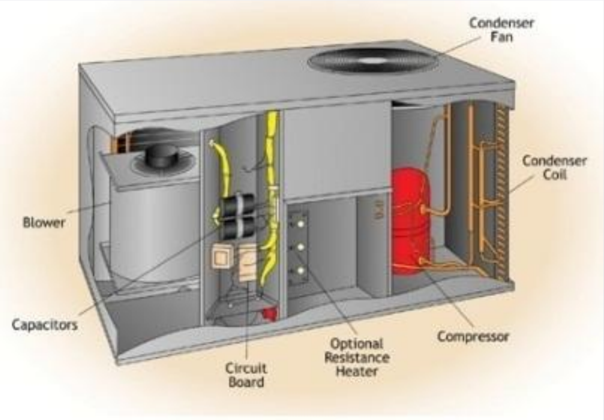
Condensation after 8.5 hours on a chilled surface intentionally held 7.8°F colder than the space DPT. Not one droplet fell under these conditions

Chilled Ceilings in Parallel with Dedicated Outdoor Air Systems: Addressing the Concerns of Condensation, Capacity, and Cost
Stanley A. Mumma, Ph.D., P.E.

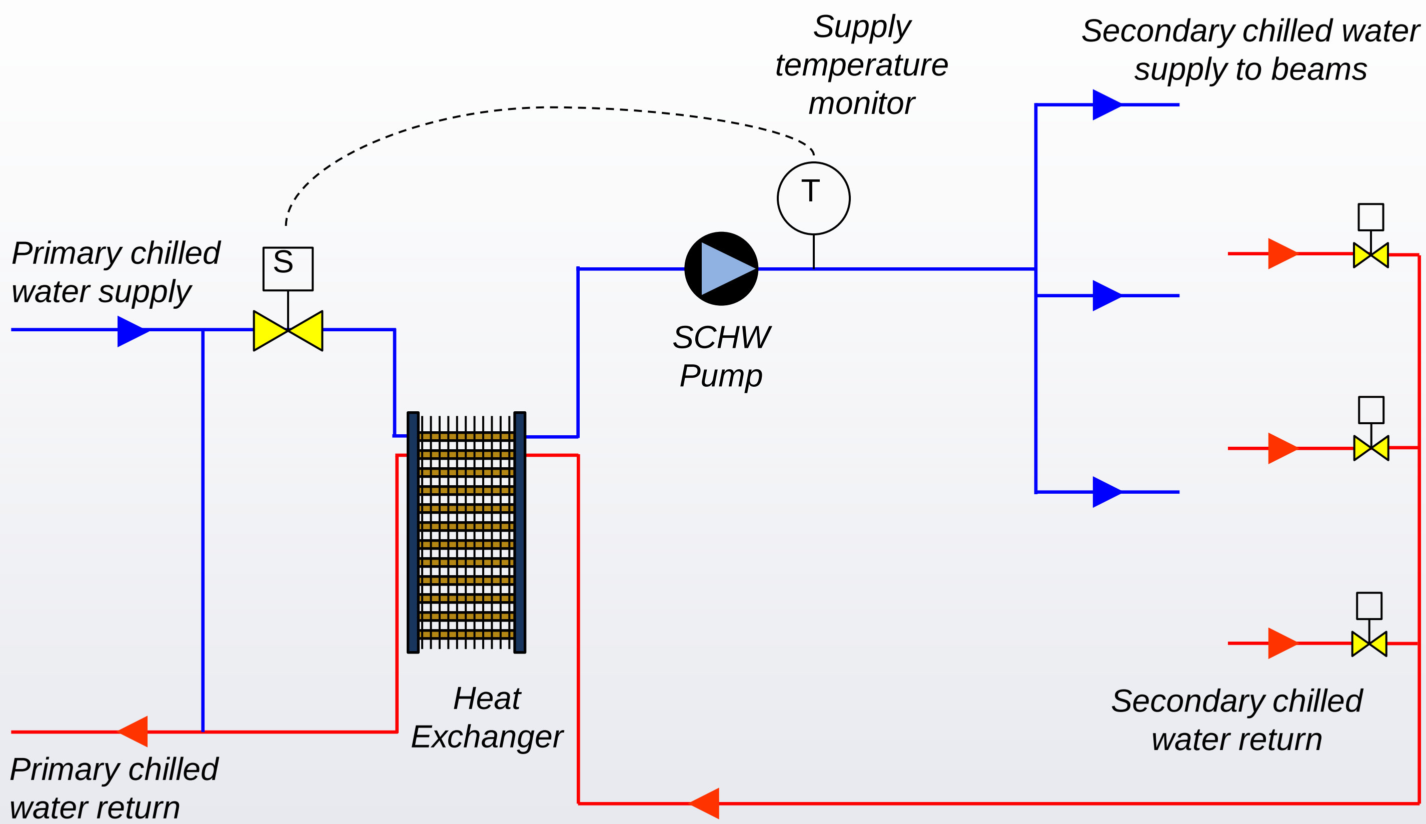


WATER SYSTEM DESIGN

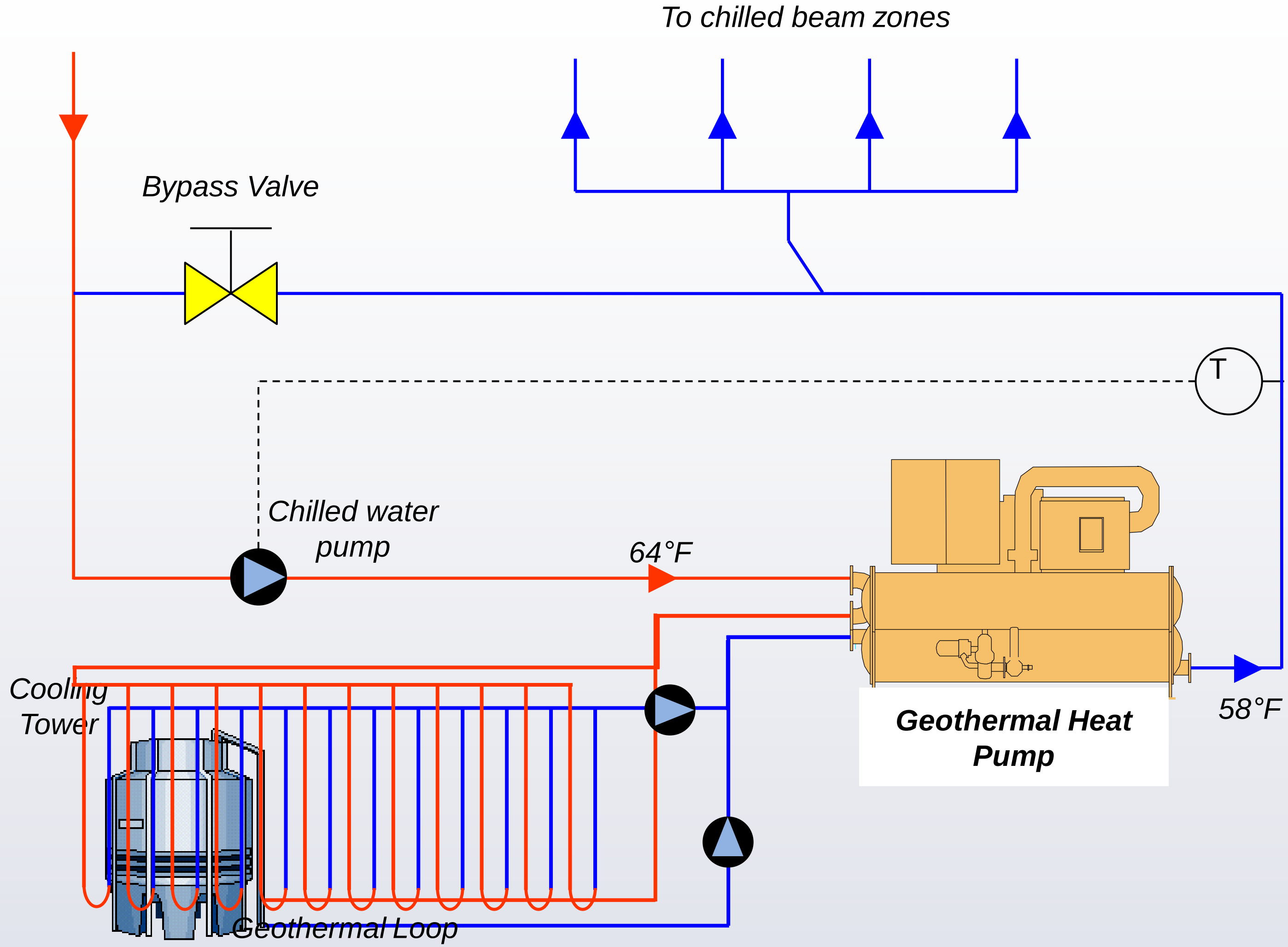
- Secondary loop
  - Tap into district CHW loop
  - Heat exchanger into return – no GPM demand
  - Can increase main plant efficiency
- Dedicated chiller & DX
  - Dehumidification by DX AHU
  - Significantly increased COP - 11+
- Twin chillers
  - One for AHU's – 6 COP
  - One for chilled beam circuit – 11+ COP



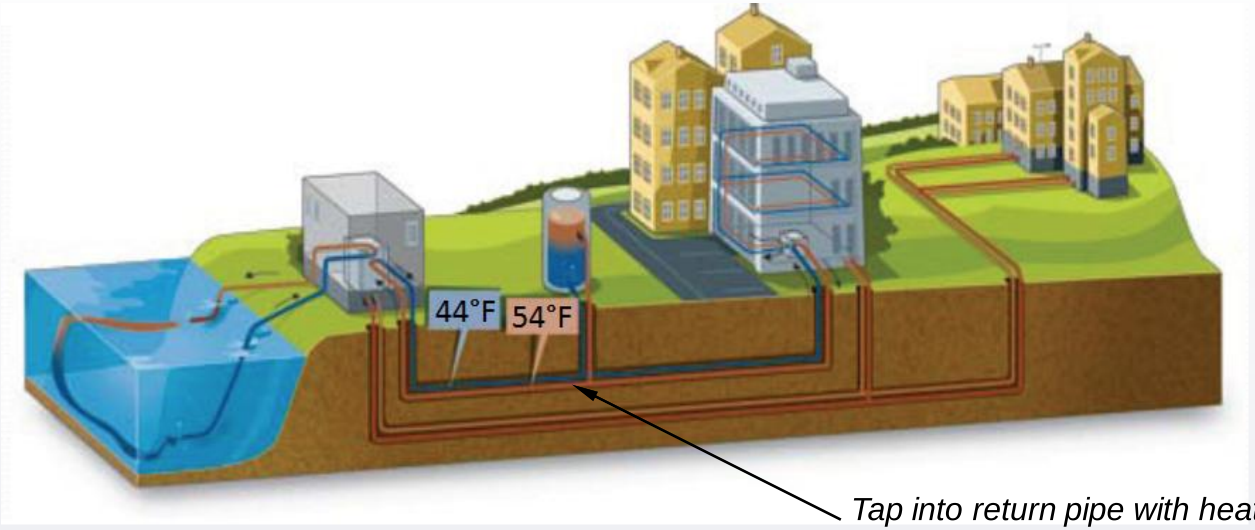
Secondary Loop



Dedicated Chiller

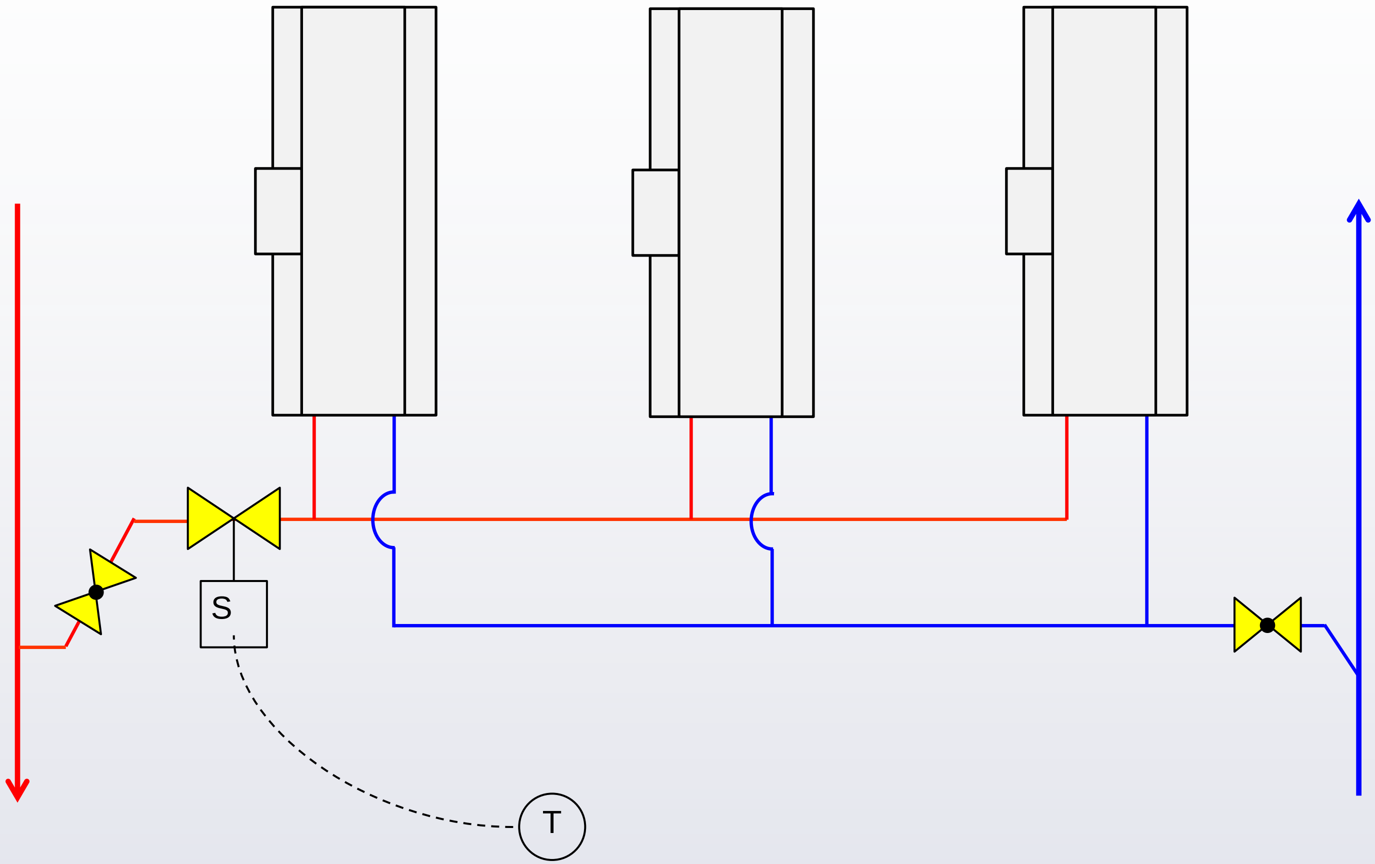


District Chilled Water Loops



Tap into return pipe with heat exchanger and secondary loop

- No demand in district loop GPM
- Increases main chiller plant COP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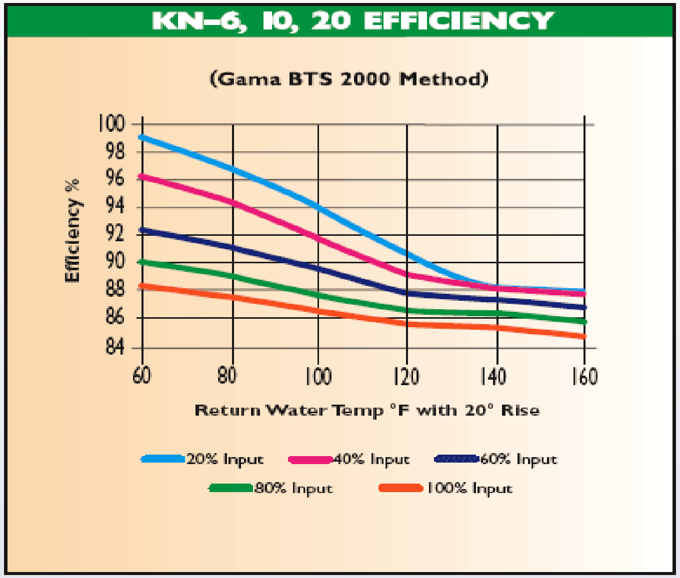
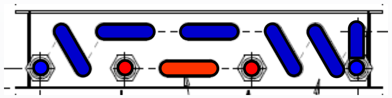
- Hot water typically 90-130°F
- Reduce boiler energy consumption by maximizing efficiency of a condensing boiler through very low return water temperatures
- Use of water to water heat pumps



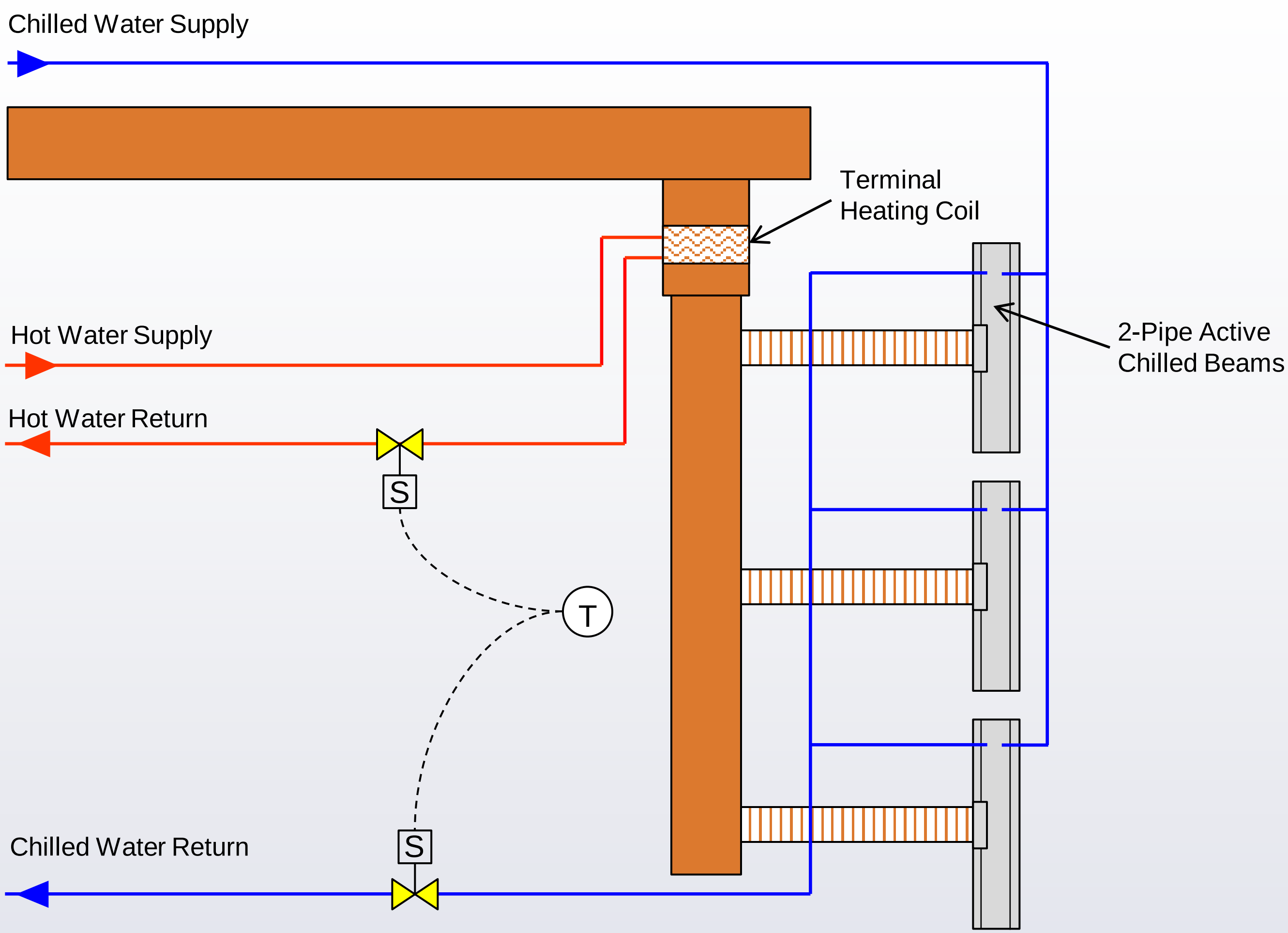
(KN boiler efficiency chart courtesy of Hydrotherm)

Advantages of 2-Pipe Beams Versus 4-Pipe



- Higher coil performance
  - 4 pipe performance is compromised
  - 75% Cooling (12 pipes)
  - 25% Heating (4 pipes)
- Fewer or shorter beams
- Lower hot water temperatures
  - 90°F for 2 pipe
  - 130°F for 4 pipe

2-Pipe Beams and Terminal Heating



CASE STUDIES

250 S. Wacker, Chicago

- 16-story tower –
  215,000 sq. ft.
  1st floor retail
  2 – 16th floor offices

- Separate HVAC systems for 1st and 16th floors

- Perimeter induction system with floor-mounted units serving 2 - 15th floors

- Interior constant volume/ variable temperature system serving
  2 – 15th floors

Building Renovated with -

- 100% glazing with E-glass (190 Btuh/Ln.ft. heat loss)
- Single duct cooling only VAV interior system
- Evaluated fan-powered VAV or Active Chilled Beam perimeter system
- Seeking LEED certification

Perimeter System Type	Existing Induction System	Proposed Fan-powered VAV System **	Proposed Active Chilled Beam System **
Design Cooling Load	262 tons (382 sq.ft./ton)	156 tons (641 sq.ft./ton)	156 tons (641 sq.ft./ton)
Primary Airflow	25,600 cfm (0.5 cfm/sq.ft.)	86,270 cfm (1.7 cfm/sq.ft.)	15,880 cfm (0.3 cfm/sq.ft.)
Fan Energy at Design	64 kW	182 kW	22 kW
Fan Energy at 70% of Design	64 kW	116 kW	22 kW
Pump Energy	28 kW	8 kW	12 kW
Combined Fan & Pump Energy	92 kW	190 kW @ Design 124 kW @ 70%	34 kW

**** Required larger ductwork/risers** **** Used existing ductwork/risers**

250 S. Wacker, Chicago

250 S. Wacker, Chicago

100 Howe Building, Kentucky

- Call center, 350,000 sq ft
- 2,200 occupants
- LEED design
- Considered radiant ceilings and passive beam systems
- Article in ASHRAE Journal, December 2009

	UFAD Alone	UFAD With Radiant Cooled Ceilings	UFAD With Passive Chilled Beams
Supply Air Quantity (cfm)	560,000	240,000	240,000
Supply Fan Power (hp)	600	280	280
Return Fan Power (hp)	280	120	120
Total Swirl Diffusers Required	5,600	2,400	2,400
Weighted Airflow (cfm/ft²)	1.6	0.7	0.7
Qualitative Flexibility	Good	Fair	Good
First Cost ($)	Reference	4,250,000	100,000
Operating Cost Payback	N/A	>50 years	<2 years

100 Howe Building, Kentucky

- Real energy results based on comparison with another building on the same campus
- Energy usage data collected over 1 year
- Electrical energy consumption reduced by 41%
- Natural gas consumption reduced by 24%

Viterbo School of Nursing, WI

- New $15.8m facility (original estimate $20m)
- 68,000 ft2, 7 floors
- Consists of labs, lecture halls and classrooms
- LEED Silver Certification
- Completion due fall 2011

HVAC First Costs
Savings Compared to VAV

- Smaller AHU’s
- Smaller ductwork
- Controls
  - Simple two position zone valves
- Electrical infrastructure costs
  - Increased pump HP more than offset by reduced fan HP

HVAC First Costs
Increases Compared to VAV

- More terminals (beams)
- More distribution piping
- More piping insulation
  - Requirement depends on chilled water temperature and dewpoint

Overall HVAC cost increase = $300,000 compared to VAV

503.2.8 Piping insulation. All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Table 503.2.8.

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Piping that conveys fluids that have a design operating temperature range between 55°F (13°C) and 105°F (41°C).
3. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electric power.
4. Runout piping not exceeding 4 feet (1219 mm) in length and 1 inch (25 mm) in diameter between the control valve and HVAC coil.

2006 INTERNATIONAL ENERGY CONSERVATION CODE®

Construction Costs

Reduced height

Construction Costs
Savings due to reduced height

Building Component	Savings	
Structural Ste[illegible]	$	7,200
M[illegible]ry (int[illegible]	$	[illegible],692
Fire[illegible]		600
St[illegible]		[illegible]
[illegible]		[illegible]87
In[illegible]		[illegible]424
F[illegible]		2,[illegible]
Curtain[illegible]		[illegible]0,500
Stairs	$	[illegible]2,500
Exterior Dryw[illegible]	$	5[illegible],249
Elevators	$	5,000
Electrical	$	30,000
Total Cost Savings	$	245,298

Overall cost neutral

Pricing provided by CD Smith Construction

Viterbo School of Nursing, WI


MAKING
FUTURE
MAGIC.

Chilled Beam Pictures

Chilled Beam Pictures

Thank You

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