ACTIVE CHILLED BEAM SYSTEMS

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• 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. ELECTRICITY CONSUMPTION

BUILDINGS (operations) 71%

INDUSTRY 27%

Courtesy of USGBC
1 Ton of Cooling

requires 550 CFM of air

or

4 GPM of water
• Many buildings heated only
• PC’s appearing on desks
• Restricted ceiling cavity
Chilled Ceilings Radiant Effect

CW Supply
59-62°F

45%
Radiant

CW Return
62-66°F

55%
Convective

76°F Dry Bulb

74°F radiant
temperature (black bulb)
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
- Increased cooling loads
  - Equipment
  - Occupancy
  - Day-lighting
- Inadequate perimeter cooling

Passive Chilled Beams
Passive Chilled Beam Operation Principle

- Soffit
- Suspension rod
- Water coil
- Perforated tile
- Fabric skirt
- Water coil
• 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
Active Chilled Beams

- Higher space loads
- Higher occupant densities
- Combined ventilation/cooling preferred
- Integration into fiber tile ceilings required
Active Chilled Beam Airflow Pattern
70% of sensible heat removed by chilled beam water coil.

Airflow requirement reduced by 70%.

Waterside Cooling 70%

Airside Cooling 30%
• 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
• 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

<table>
<thead>
<tr>
<th>Source</th>
<th>Technology</th>
<th>Application</th>
<th>% Saving*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE 2010 Technology Awards</td>
<td>Passive Chilled Beams</td>
<td>Call Center</td>
<td>41</td>
</tr>
<tr>
<td>ASHRAE Journal 2007</td>
<td>Active Chilled Beams</td>
<td>Laboratory</td>
<td>57</td>
</tr>
<tr>
<td>SmithGroup</td>
<td>Active Chilled Beams</td>
<td>Offices</td>
<td>24</td>
</tr>
</tbody>
</table>

*Compared to VAV
• 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?
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
To chilled beam zones

Bypass Valve

Chilled water pump

64°F

Geothermal Heat Pump

58°F

Cooling Tower

Geothermal Loop
District Chilled Water Loops

• No demand in district loop GPM
• Increases main chiller plant COP
Reverse Return
• 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

Chilled Water Supply

Hot Water Supply

Hot Water Return

Chilled Water Return

Terminal Heating Coil

2-Pipe Active Chilled Beams
CASE STUDIES
• 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
<table>
<thead>
<tr>
<th>Perimeter System Type</th>
<th>Existing Induction System</th>
<th>Proposed Fan-powered VAV System **</th>
<th>Proposed Active Chilled Beam System **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Cooling Load</td>
<td>262 tons (382 sq.ft./ton)</td>
<td>156 tons (641 sq.ft./ton)</td>
<td>156 tons (641 sq.ft./ton)</td>
</tr>
<tr>
<td>Primary Airflow</td>
<td>25,600 cfm (0.5 cfm/sq.ft.)</td>
<td>86,270 cfm (1.7 cfm/sq.ft.)</td>
<td>15,880 cfm (0.3 cfm/sq.ft.)</td>
</tr>
<tr>
<td>Fan Energy at Design</td>
<td>64 kW</td>
<td>182 kW</td>
<td>22 kW</td>
</tr>
<tr>
<td>Fan Energy at 70% of Design</td>
<td>64 kW</td>
<td>116 kW</td>
<td>22 kW</td>
</tr>
<tr>
<td>Pump Energy</td>
<td>28 kW</td>
<td>8 kW</td>
<td>12 kW</td>
</tr>
<tr>
<td>Combined Fan &amp; Pump Energy</td>
<td>92 kW</td>
<td>190 kW @ Design 124 kW @ 70%</td>
<td>34 kW</td>
</tr>
</tbody>
</table>

** Required larger ductwork/risers  ** Used existing ductwork/risers
• Call center, 350,000 sq ft
• 2,200 occupants
• LEED design
• Considered radiant ceilings and passive beam systems
• Article in ASHRAE Journal, December 2009

<table>
<thead>
<tr>
<th></th>
<th>UFAD Alone</th>
<th>UFAD With Radiant Cooled Ceilings</th>
<th>UFAD With Passive Chilled Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Air Quantity (cfm)</td>
<td>560,000</td>
<td>240,000</td>
<td>240,000</td>
</tr>
<tr>
<td>Supply Fan Power (hp)</td>
<td>600</td>
<td>280</td>
<td>280</td>
</tr>
<tr>
<td>Return Fan Power (hp)</td>
<td>280</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Total Swirl Diffusers Required</td>
<td>5,600</td>
<td>2,400</td>
<td>2,400</td>
</tr>
<tr>
<td>Weighted Airflow (cfm/ft²)</td>
<td>1.6</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Qualitative Flexibility</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>First Cost ($)</td>
<td>Reference</td>
<td>4,250,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Operating Cost Payback</td>
<td>N/A</td>
<td>&gt;50 years</td>
<td>&lt;2 years</td>
</tr>
</tbody>
</table>
• 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%
- 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
Construction Costs

Reduced height

Floor heights reduced 10”-14

Overall height reduced by 6’
## Construction Costs

**Savings due to reduced height**

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Steel</td>
<td>$ 7,200</td>
</tr>
<tr>
<td>Masonry (int/ext)</td>
<td>$ 97,692</td>
</tr>
<tr>
<td>Fire-Proofing</td>
<td>$ 600</td>
</tr>
<tr>
<td>Steel Studs</td>
<td>$ 22,824</td>
</tr>
<tr>
<td>Air Barrier</td>
<td>$ 8,787</td>
</tr>
<tr>
<td>Insulation</td>
<td>$ 3,424</td>
</tr>
<tr>
<td>Exterior Caulking</td>
<td>$ 1,522</td>
</tr>
<tr>
<td>Curtain Wall</td>
<td>$ 10,500</td>
</tr>
<tr>
<td>Stairs</td>
<td>$ 2,500</td>
</tr>
<tr>
<td>Exterior Drywall</td>
<td>$ 55,249</td>
</tr>
<tr>
<td>Elevators</td>
<td>$ 5,000</td>
</tr>
<tr>
<td>Electrical</td>
<td>$ 30,000</td>
</tr>
<tr>
<td><strong>Total Cost Savings</strong></td>
<td><strong>$ 245,298</strong></td>
</tr>
</tbody>
</table>

*Overall cost neutral*

Pricing provided by CD Smith Construction
Chilled Beam Pictures
Thank You
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