Designing Either Chilled Beam or VAV Systems for High Performance

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"High-Performance" Systems

- Brief review of today's technical session
  - Overview of chilled beam systems
  - Assess marketed advantages of chilled beams vs. VAV
  - Discuss challenges of applying chilled beam systems
- "High-performance" chilled beam systems
- "High-performance" VAV systems

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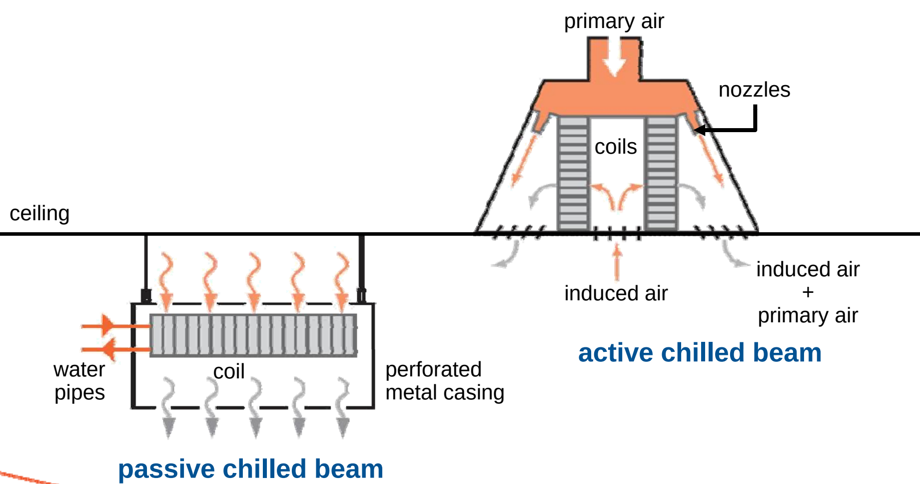
Passive or Active Chilled Beams



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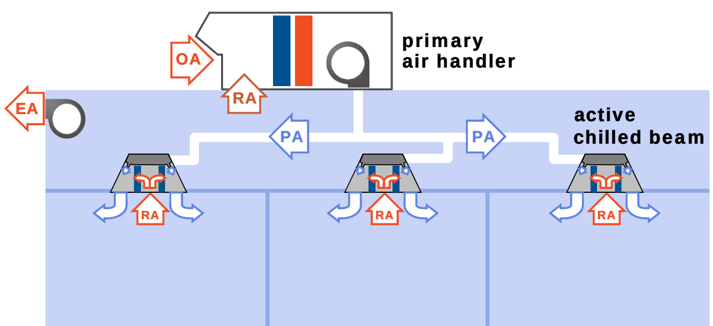
active chilled beams
Primary Air System



Primary air must be sufficiently drier than space:
- **to offset space latent load, and**
- **to keep space DP below chilled beam surface temp**

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active chilled beam systems compared to VAV systems

Summary of Today's Technical Session

Potential advantages of ACB

- Smaller ductwork and smaller air handlers
  - Primary airflow < supply airflow, but likely > outdoor airflow
- Low sound levels
- Impact on overall system energy?
  - Primary airflow < supply airflow, but constant airflow
  - Warm water for beams, but cold water primary AHU
  - Increased pumping energy
  - No DCV, limited airside economizing

Challenges of ACB

- High installed cost
- Need to prevent condensation
- Risk of water leaks
- No filtration of local recirculated air
- Limited heating capability

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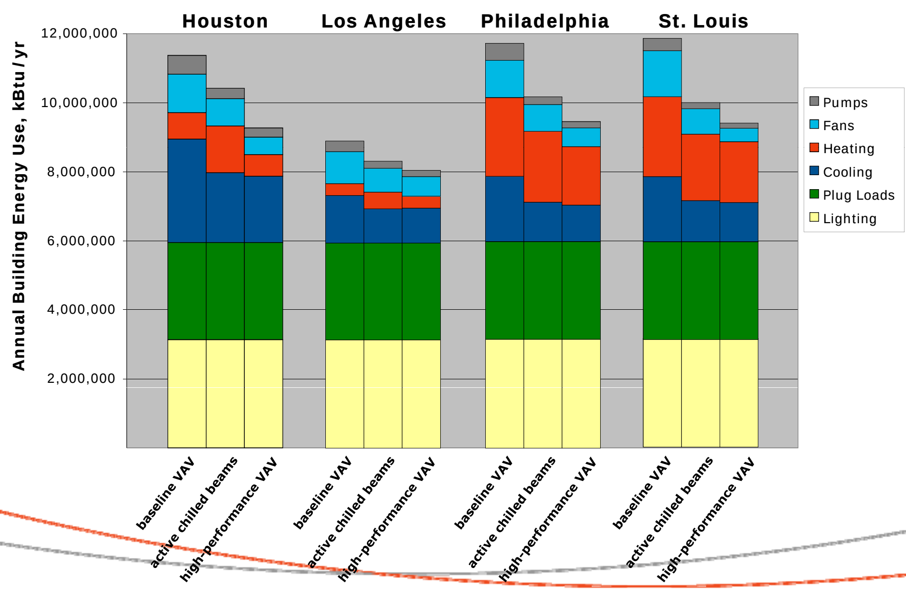
Example Energy Analysis



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office building

Example Energy Analysis

- "Baseline" chilled-water VAV system
  - ASHRAE 90.1-2007, Appendix G (55°F supply air)
- Active chilled beam system
  - Four-pipe active chilled beams
  - Separate primary AHUs for perimeter and interior areas (with SAT reset and economizers)
  - Separate water-cooled chiller plants (low-flow plant supplying primary AHUs)
- "High-performance" chilled-water VAV system
  - 48°F supply air (ductwork not downsized)
  - Optimized VAV system controls (ventilation optimization, SAT reset)
  - Parallel fan-powered VAV terminals
  - Low-flow, water-cooled chiller plant

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"High-Performance" Systems

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“High Performance” Chilled Beam Systems

- How can active chilled beam systems be designed differently for “high performance”?

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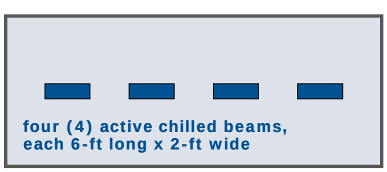
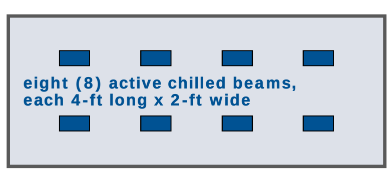
ACB challenges
High Installed Cost

- Limited cooling capacity = lots of ceiling space
  – Warmer water temperature requires more coil surface area
  – Induction with low static pressures requires more coil surface area to keep airside pressure drop low



Example: 1000-ft^2 office space



Example: 1000-ft^2 classroom

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System design variable	Impact on installed cost of the chilled beams	Impact on performance of the overall system
2-pipe versus 4-pipe chilled beams	A 2-pipe beam provides more cooling capacity than a 4-pipe beam because more coil surface is available	Using 2-pipe beams requires a separate heating system, otherwise it can result in poorer comfort control because either cold water or warm water is delivered to all zones
Primary airflow rate (cfm)	Increasing the primary airflow rate through the nozzles results in more air being induced from the space, which increased the capacity of the chilled beam coils	Increasing the primary airflow rate increases primary AHU fan energy use, increases noise in the space, and requires a larger primary AHU and larger ductwork
Inlet static pressure of the primary air	Increasing the static pressure at the inlet to the nozzles results in more air being induced from the space, which increased the capacity of the chilled beam coils	Increasing the inlet pressure increases primary AHU fan energy use, and increases noise in the space
Dry-bulb temperature of the primary air	Delivering the primary air at a colder temperature means that less of the space sensible cooling load needs to be offset by the chilled beams	Using a colder primary-air temperature may cause the space to overcool and low sensible cooling loads, thus requiring the chilled beam (or separate heating system) to add heat to prevent overcooling space
Entering water temperature	Supplying colder water to the chilled beam increases the cooling capacity of the beam	Using a colder water temperature requires the space dew point to be lower to avoid condensation, which means the primary air needs to be dehumidified to a lower dew point
Water flow rate (gpm)	Increasing the water flow rate increases the cooling capacity of the beam	Increasing the water flow rate increases pump energy use and requires larger pipes and pumps

“High Performance” Chilled Beam Systems

- How can active chilled beam systems be designed differently for “high performance”?
  - Use two-pipe beams as much as possible
    - Use primary air system for morning warm-up
    - Consider using a separate heating system

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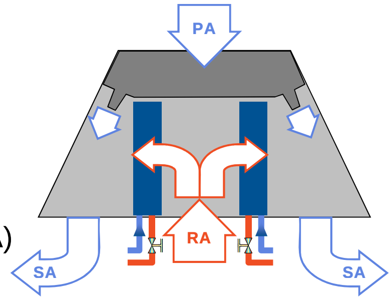
active chilled beams
Determining Primary Airflow Rate

- Primary airflow (PA) is based on largest of:
  - Minimum outdoor airflow required (ASHRAE 62.1)
  - Airflow required to offset space latent load (depends on dew point of PA)
  - Airflow needed to induce sufficient room air (RA) to offset the space sensible cooling load



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active chilled beams

Determining Primary Airflow Rate

	Example: office space	
Minimum OA per ASHRAE 62.1 (to achieve LEED IEQc2)	0.085 cfm/ft² (0.085 × 1.3 = 0.11 cfm/ft²)	
ACB system		
Airflow required to offset space latent load	0.085 cfm/ft²	(DPT_{PA} = 47°F)
	0.11 cfm/ft²	(DPT_{PA} = 49°F)
	0.36 cfm/ft²	(DPT_{PA} = 53°F)
Airflow needed to induce sufficient room air to offset space sensible cooling load	0.36 cfm/ft² (four, 6-ft long beams)	(55°F primary air)
VAV system		
Airflow needed to offset space sensible cooling load	0.90 cfm/ft² (55°F supply air)	

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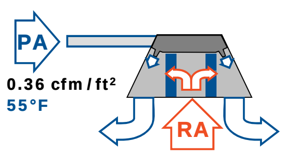
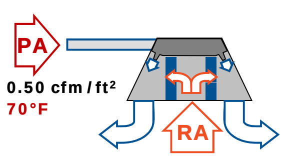
example office space

Cold vs. Neutral Primary Air



"Cold" (55°F) primary-air temperature

- four (4) ACBs, each 6-ft long x 2-ft wide
- primary airflow at design conditions = 0.36 cfm/ft²
- total water flow = 6.0 gpm



"Neutral" (70°F) primary-air temperature

- six (6) ACBs, each 6-ft long x 2-ft wide
- primary airflow at design conditions = 0.50 cfm/ft²
- total water flow = 9.0 gpm

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"High Performance" Chilled Beam Systems

- How can active chilled beam systems be designed differently for "high performance"?
  - Use two-pipe beams as much as possible
    - Use primary air system for morning warm-up
    - Consider using a separate heating system
  - Minimize primary airflow required
    - Deliver primary air at a cold (rather than neutral) temperature
    - Use multiple, smaller primary AHUs to allow SAT reset (maximize cooling benefit, minimize need for reheat)

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active chilled beams

Determining Primary Airflow Rate

	Example: K-12 classroom	
Minimum OA per ASHRAE 62.1 (to achieve LEED IEQc2)	0.47 cfm/ft^2 (0.47 × 1.3 = 0.61 cfm/ft^2)	
ACB system		
Airflow required to offset space latent load	0.47 cfm/ft^2 0.61 cfm/ft^2 1.20 cfm/ft^2	(DPT_{PA} = 44°F) (DPT_{PA} = 47°F) (DPT_{PA} = 51°F)
Airflow needed to induce sufficient room air to offset space sensible cooling load	0.47 cfm/ft^2 (eight, 4-ft long beams)	(55°F primary air)
VAV system		
Airflow needed to offset space sensible cooling load	1.20 cfm/ft^2 (55°F supply air)	

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ACB challenges

Need to Prevent Condensation

- Primary air system used to limit indoor dew point (typically below 55°F)
- Warm chilled-water temperatures delivered to beams (typically between 58°F and 60°F)

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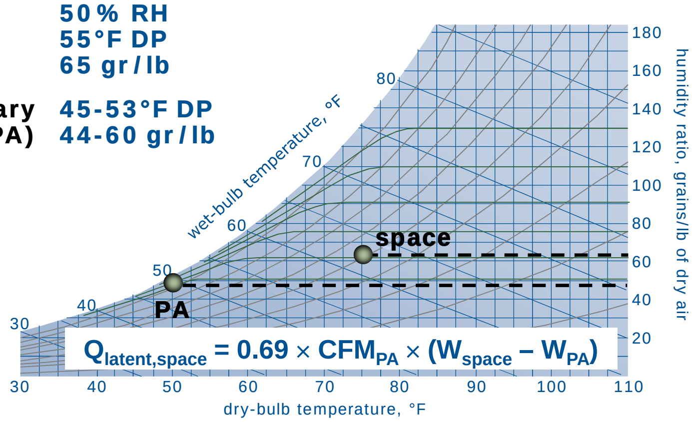
space 75°F DB
50% RH
55°F DP
65 gr/lb

primary air (PA) 45-53°F DP
44-60 gr/lb



Primary air must be sufficiently drier than the space

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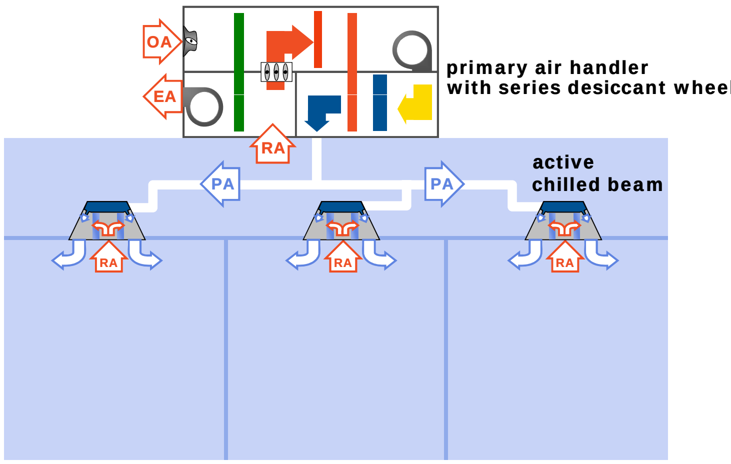
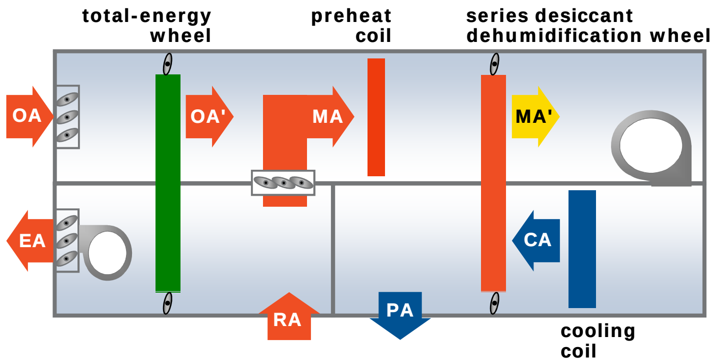
active chilled beams

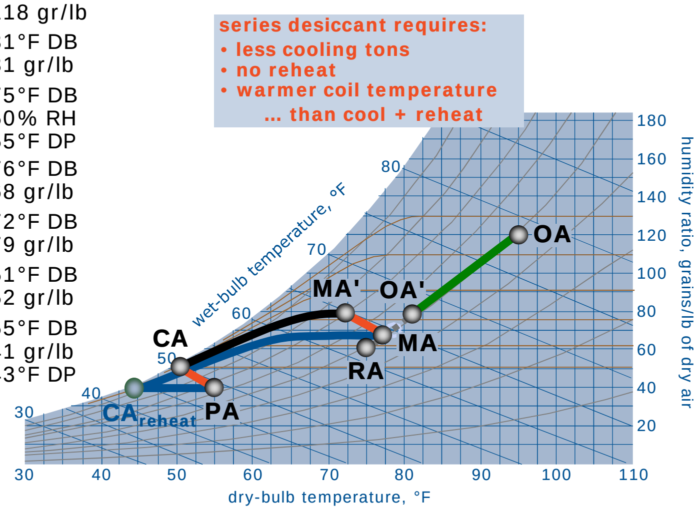
Primary Air System



Primary AHU for ACB Systems



OA	95°F DB 118 gr/lb
OA'	81°F DB 81 gr/lb
RA	75°F DB 50% RH 55°F DP
MA	76°F DB 68 gr/lb
MA'	72°F DB 79 gr/lb
CA	51°F DB 52 gr/lb
PA	55°F DB 41 gr/lb 43°F DP



primary AHU with series desiccant wheel

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"High Performance" Chilled Beam Systems

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    - Consider using a separate heating system
  - Minimize primary airflow required
    - Deliver primary air at a cold (rather than neutral) temperature
    - Use multiple, smaller primary AHUs to allow SAT reset (maximize cooling benefit, minimize need for reheat)
    - Deliver primary air at a lower dew point (may even allow for the delivery of colder water to beams)

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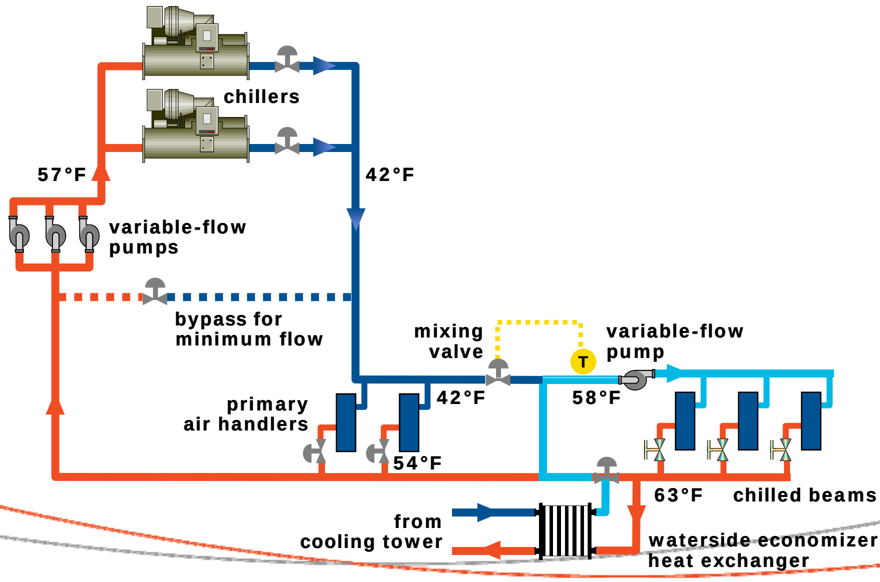
Waterside Economizer



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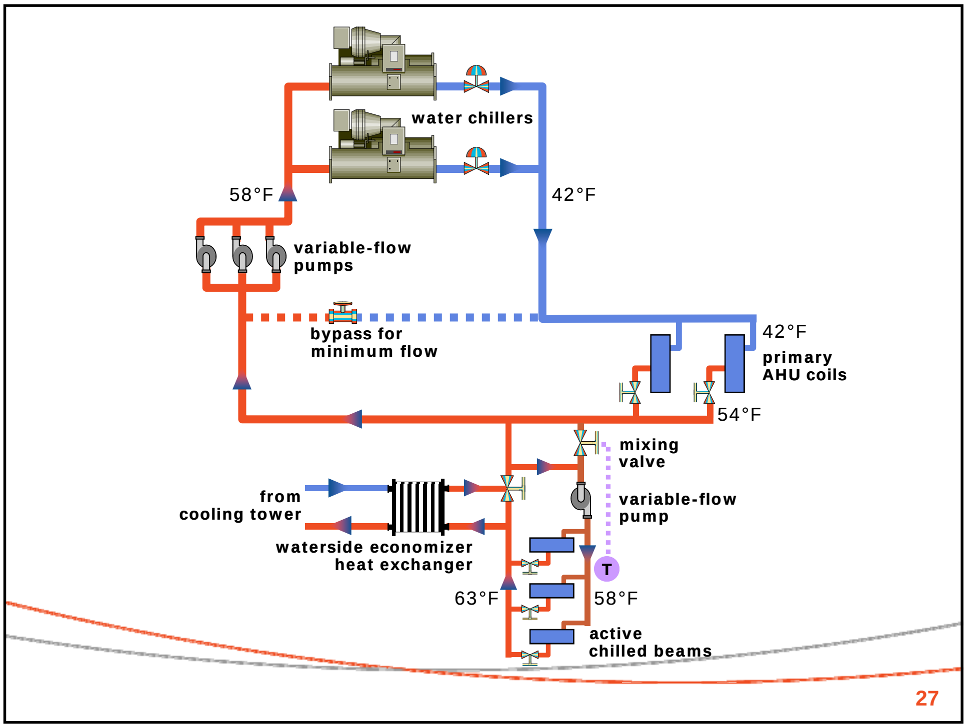

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    - Deliver primary air at a lower dew point
  - Incorporate a waterside economizer, if possible

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“High Performance” VAV Systems

- How are VAV systems being designed differently today for “high performance”?
  - Optimized VAV system controls

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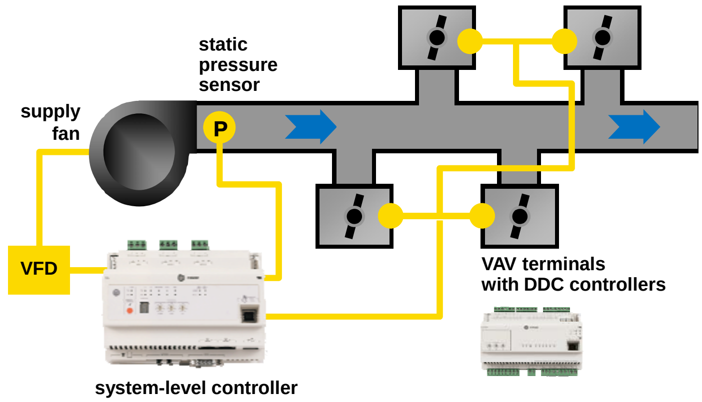
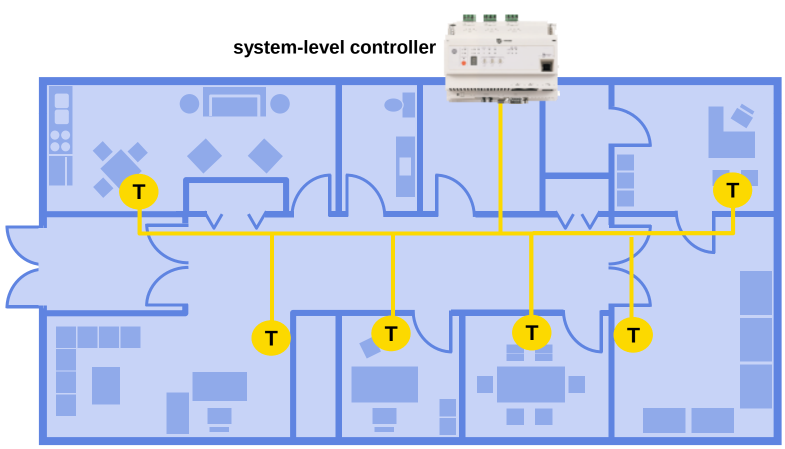
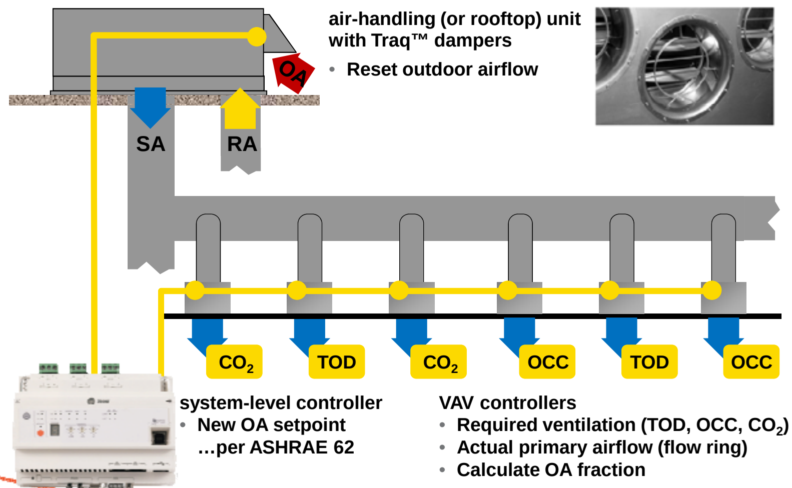
Fan-Pressure Optimization



Supply-Air Temperature Reset



Ventilation Optimization



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"High Performance" VAV Systems

- How are VAV systems being designed differently today for "high performance"?
  - Optimized VAV system controls
  - Cold air distribution

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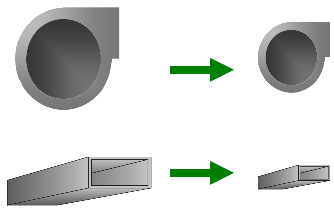
Lower Supply-Air Temperature



- Reduces supply airflow
  - Less supply fan energy and less fan heat gain
  - Smaller fans, air handlers, VAV terminals, and ductwork
- Can reduce HVAC installed cost
- Can reduce building construction cost
- Improves occupant comfort
  - Lowers indoor humidity levels
  - Lowers indoor sound levels

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"High Performance" VAV Systems

- How are VAV systems being designed differently today for "high performance"?
  - Optimized VAV system controls
  - Cold air distribution
  - Parallel fan-powered VAV terminals

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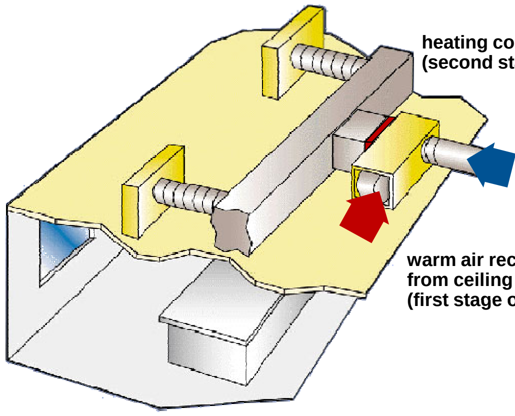
Parallel Fan-Powered VAV



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"High Performance" VAV Systems

- How are VAV systems being designed differently today for "high performance"?
  - Optimized VAV system controls
  - Cold air distribution
  - Parallel fan-powered VAV terminals
  - "High-performance" chilled-water system

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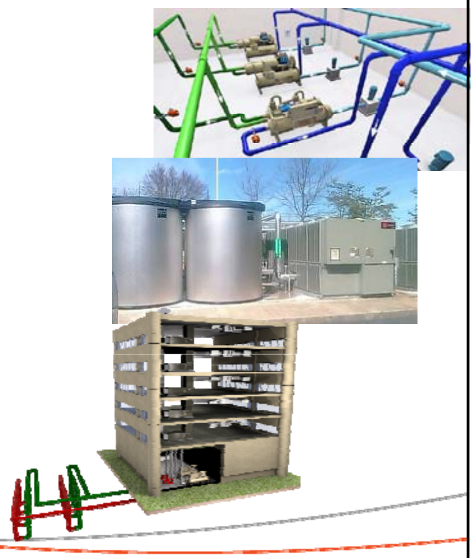
"High-Performance" Chilled-Water System

- Low flow, low temperature
- Ice storage
- Variable primary flow
- High-efficiency chillers
- Optimized plant controls
- Waterside heat recovery
- Central geothermal



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Summary

- Chilled beam and VAV systems
  each have advantages and drawbacks

- We need to move toward designing
  "high-performance" systems…
  not just the way it's always been done!

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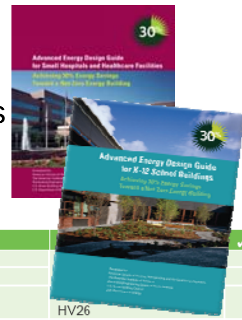
Advanced Energy Design Guides

www.ashrae.org/freeaedg

- Funded by U.S. Dept of Energy
- Climate-specific recommendations for achieving 30% or 50% energy savings (envelope, lighting, HVAC, water heating)
- Based on building energy simulations



Item	Component	Recommendation		✓
Packaged Rooftop VAV System	Rooftop air conditioner (≥240 kBtu/h)	10.0 EER and 10.4 IPLV		
	Gas furnace (≥225 kBtu/h)	80% E_c		
	Gas boiler	85% E_c	HV26	
	Economizer	>54 kBtu/h	HV13	
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
	Fans	1.3 hp/1000 cfm	HV19	

Item	Component	Recommendation	How-To Tip	✓
VAV and Chiller System	Air-cooled chiller efficiency	9.6 EER and 11.5 IPLV	HV6–8, HV10, HV25	
	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV6–8, HV10, HV25	
	Gas boiler	85% E_c	HV6–7, HV10, HV26	
	Economizer	>54 kBtu/h	HV13	
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
	Fans	1.3 hp/1000 cfm	HV19	

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Advanced Energy Design Guides

AEDG for Small or Medium Office Buildings

- "High-performance rooftop VAV systems are included as an option to achieve **50%** energy savings

AEDG for K-12 Schools

- Both rooftop VAV and chilled-water VAV systems are included as options to achieve **30%** energy savings

AEDG for Small Hospitals and Healthcare Facilities

- Both rooftop VAV and chilled-water VAV systems are included as options to achieve **30%** energy savings

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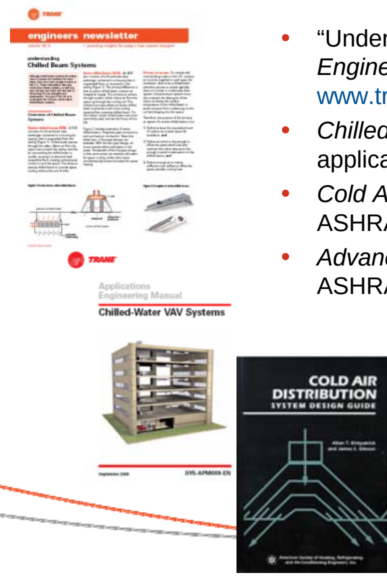
Additional Resources



- "Understanding Chilled Beam Systems," Trane *Engineers Newsletter* ADM-APN034-EN (2009), www.trane.com/engineersnewsletter
- *Chilled-Water VAV Systems*, Trane application manual SYS-APM008-EN (2009)
- *Cold Air Distribution System Design Guide*, ASHRAE (1996)
- *Advanced Energy Design Guide* series, ASHRAE, www.ashrae.org/freeaedg

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