Chilled Beams

The new system of choice?

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History of Chilled Beams

- Chilled beams were developed in Norway in 1975.
- They have been used successfully in Europe for 20 years, where they have become standard practice.
- Chilled beam technology is emerging in the U.S. as an alternative to conventional systems such as VAV.

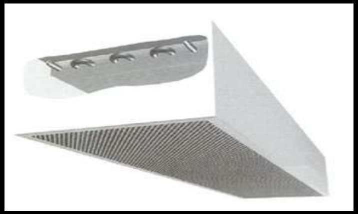
US Installations:

- Astra Zeneca – Boston, MA
- Penn State University – Philedelphia, PA
- Harvard University – Boston, MA
- Portland Center Stage – Portland, OR
- Tahoe Center for Environmental Sciences – Tahoe, NV
- Clemson University – Clemson, SC
- University of Wisconsin – Madison, WI

What is a Chilled Beam?

There are two types of Chilled Beams: Passive and Active. Common to each, is a cooling coil which provides radiant cooling via circulated cool water. Chilled beams can be either recessed in the ceiling or exposed below the ceiling. Multi-Service Chilled Beams are also available.

- Passive Chilled Beams consist of a cooling coil in an enclosure.
- Active Chilled Beams provide ventilation air to a space in addition to cooling.
- Multi-Service Chilled Beams can be either Active or Passive. They can integrate a wide variety of other building services such as lighting, speaker systems, IT systems, Sprinkler heads, photocells, etc.
- Four Pipe Heating and cooling chilled beams are available.

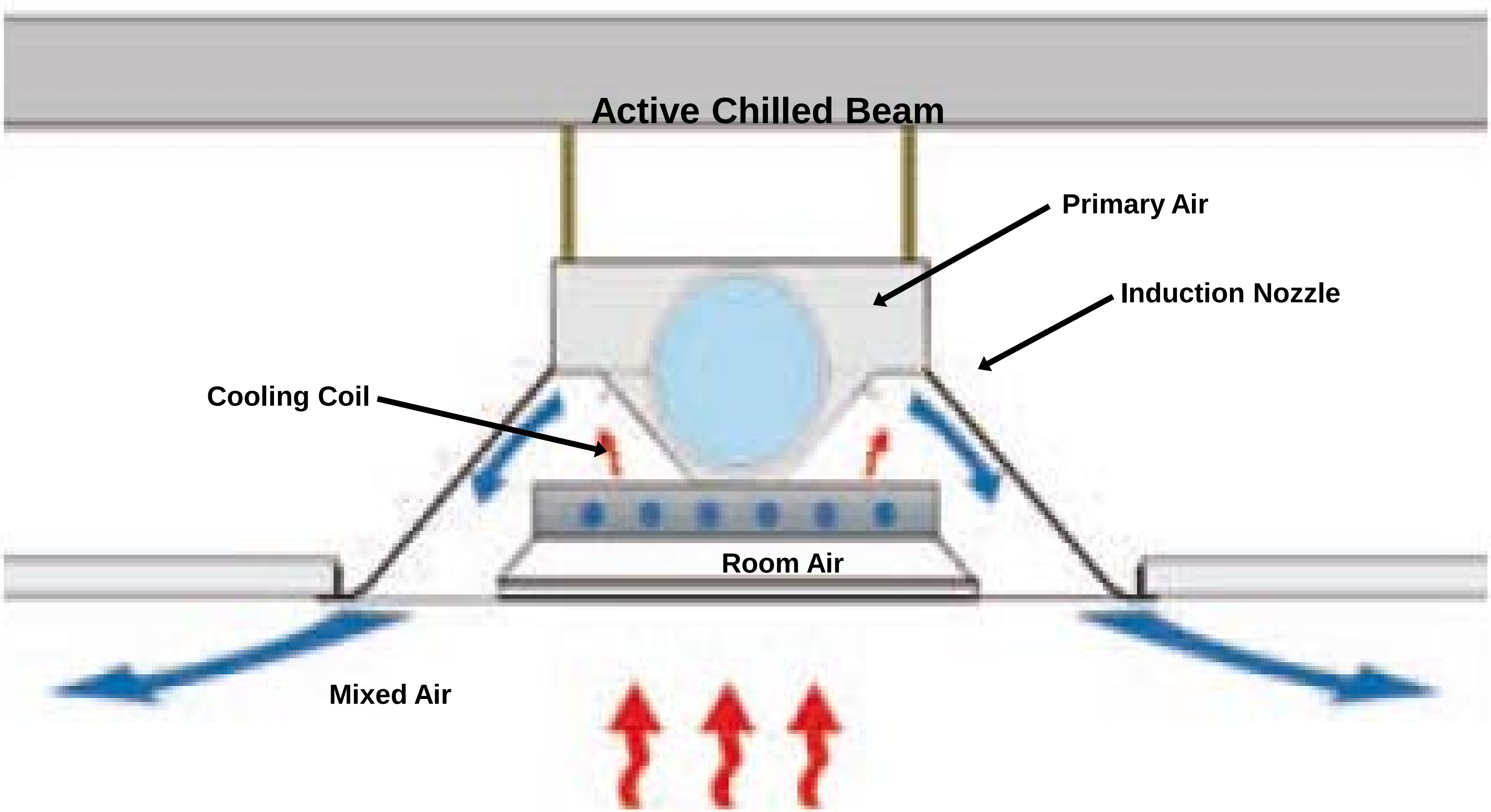


Passive Chilled Beam

Active Chilled Beam

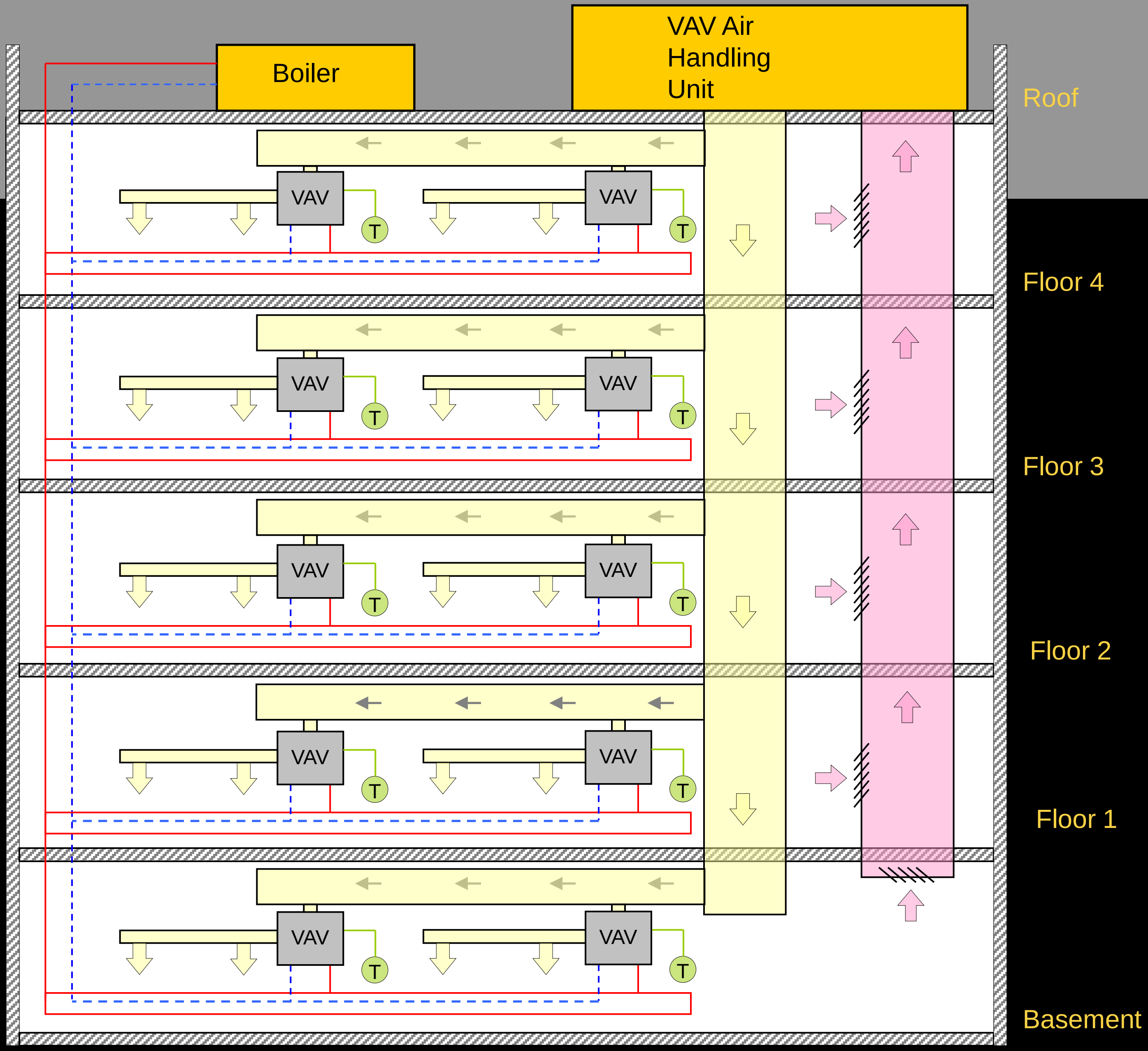
Multi-Service Chilled Beam

How does an Active Chilled Beam work?

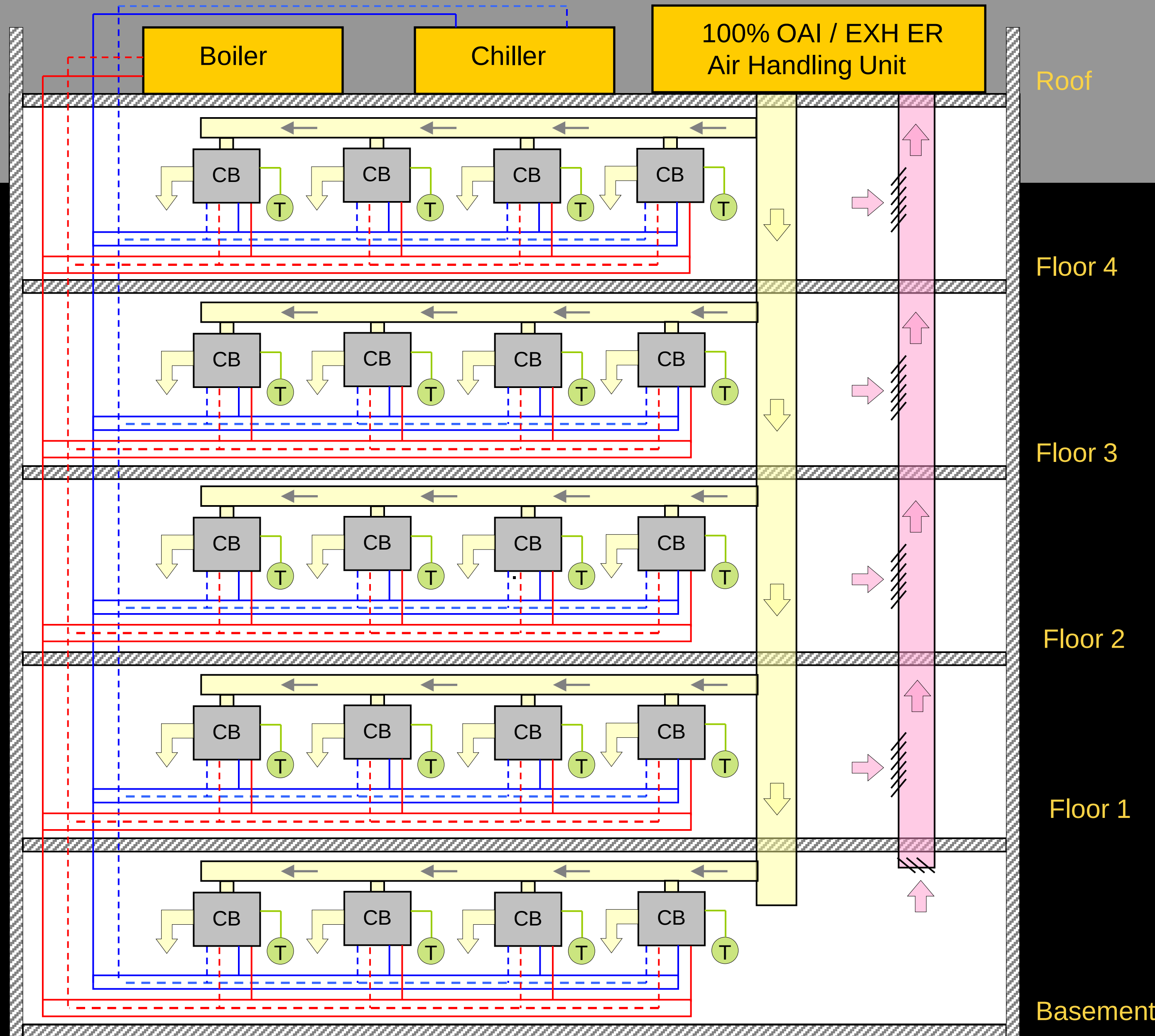


Chilled Beam Example

Active Chilled Beam



Conventional VAV System Diagram



Chilled Beam System Diagram

Advantage of Chilled Beams: Simple System

Simple to design and control

- Constant volume supply air system
- Easy ASHRAE 62 ventilation calculation
- Less complicated AHU controls
- Less complicated terminal unit controls
- No cooling coil condensate

Advantage of Chilled Beams: Less Supply Air

50% - 65% less supply air required

- Smaller ductwork
- Smaller air handling units

Chilled Beam Supply Air Ductwork Example

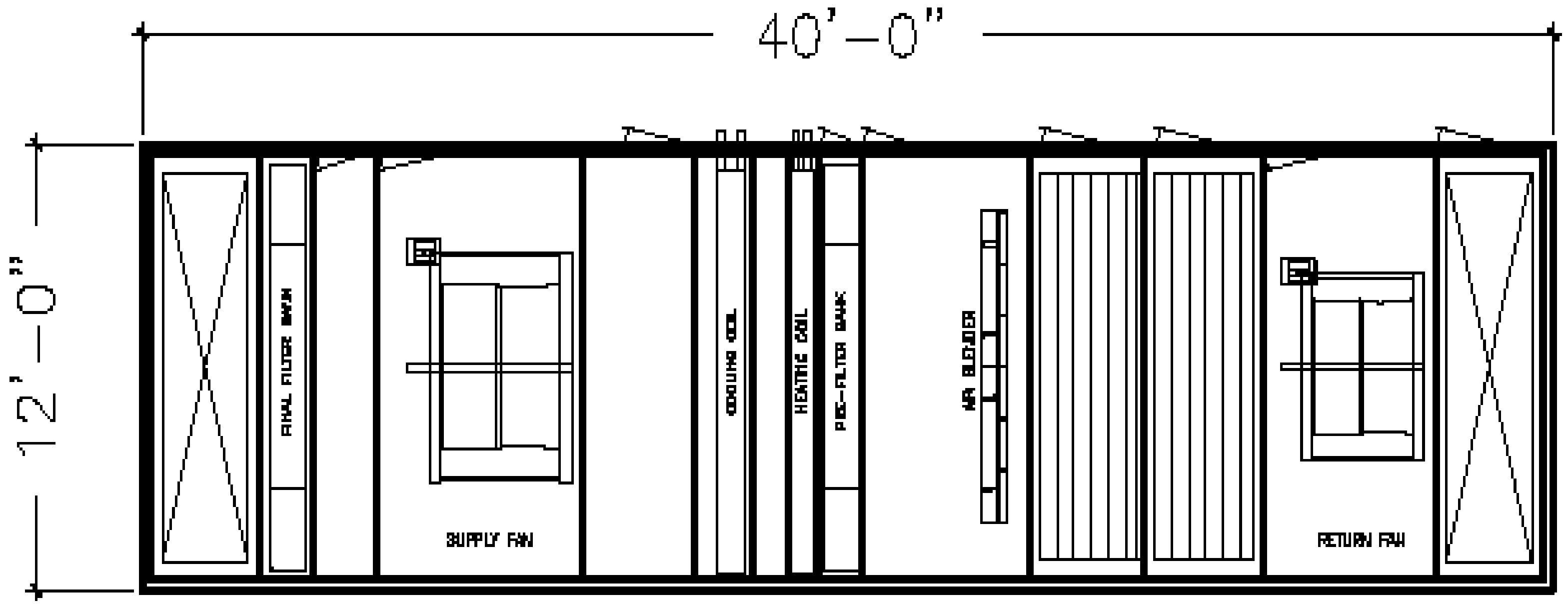
Chilled Beam vs. VAV AHU Size Comparison

<u>Building Example:</u>

40,000 SF VAV system @ 0.8 CFM/SF = 32,000 CFM

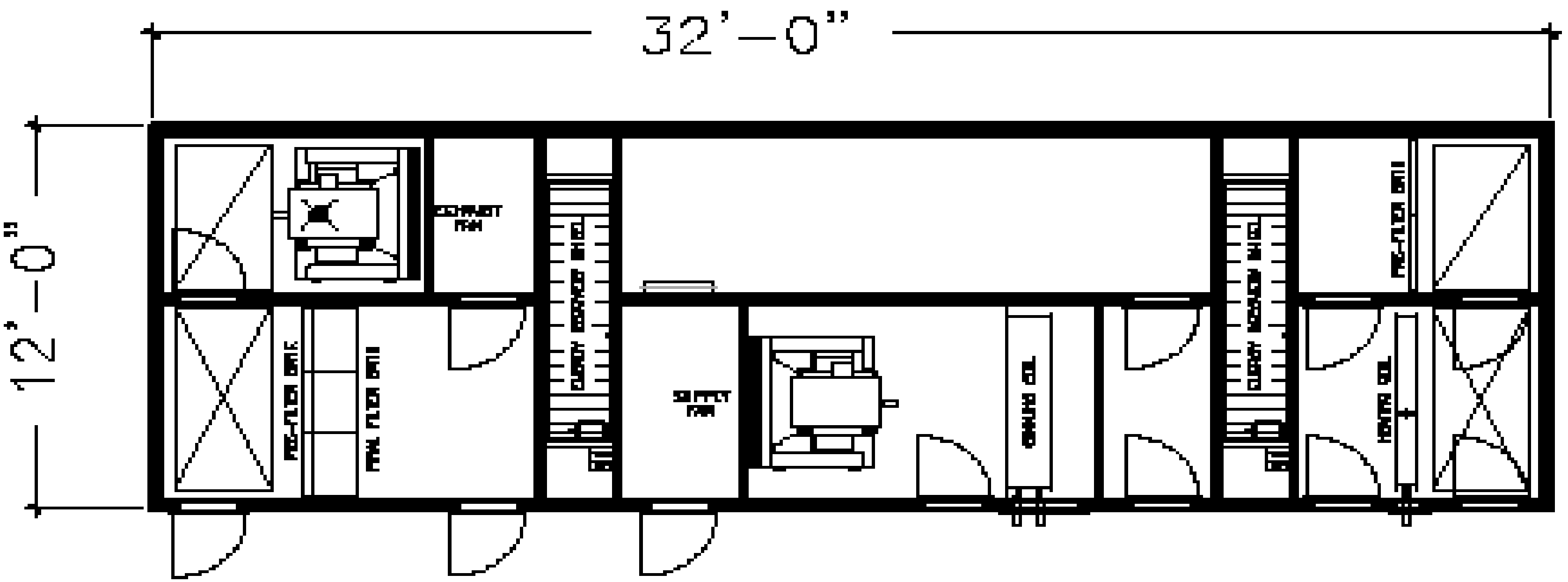
40,000 SF Chilled Beam System @ 40% of VAV = 13,000 CFM

VAV AHU Physical Size Example



TYPICAL 32,000 CFM VAV AIR HANDLING UNIT

ER AHU Physical Size Example



TYPICAL 13,000 ER AIR HANDLING UNIT

Advantage of Chilled Beams: Smaller Ductwork

Reduces ceiling space

- Compared to large VAV systems 50,000 CFM and greater, a chilled beam system can reduce ceiling space by as much as 18 inches
- Compared to small VAV systems 20,000 CFM and less, a chilled beam system can reduce ceiling space by as much as 12 inches

Advantage of Chilled Beams: Less Mechanical Space

Less building floor area required

- Reduced mechanical room size
- Reduced mechanical shaft size

Advantage of Chilled Beams: Lower Construction Cost

Reduces building construction cost

- Reduced floor to floor height lowers exterior wall cost
- Size of chilled beams installed in ceilings lowers ceiling system cost
- Reduced mechanical and shaft floor area lowers floor, roof and wall cost

Advantage of Chilled Beams: Less Maintenance

Almost no maintenance required

- No moving parts
- No filters to maintain
- Most manufacturers units are easily serviced through the removable room air inlet grille
- Requires minimal cleaning. Typically remains dust and dirt free

Lay-In Ceiling Chilled Beam Example

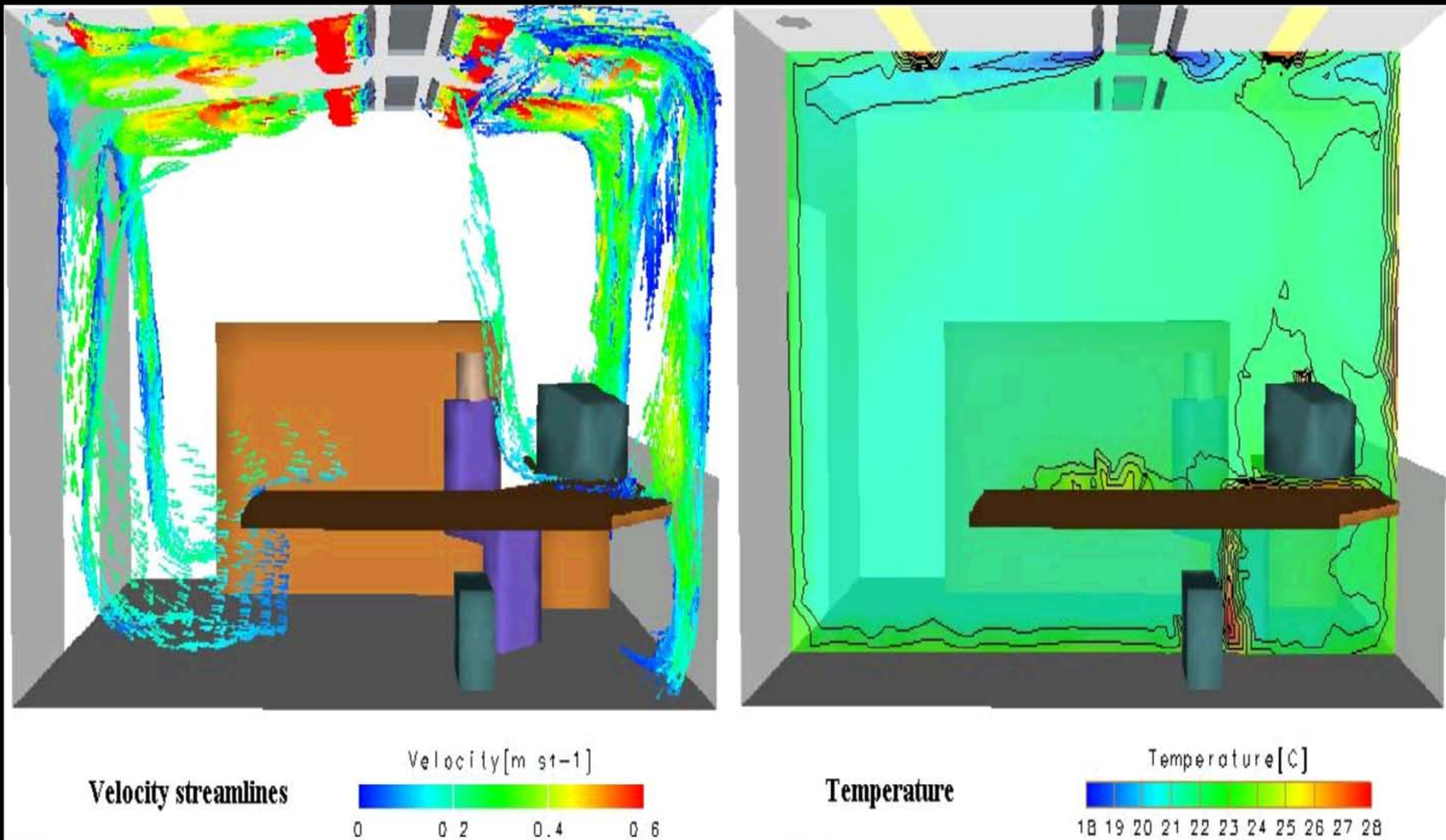
Exposed Ceiling Chilled Beam Example

Advantage of Chilled Beams: Increased Comfort

Overall occupant comfort is improved

- Individual room temperature control is achieved at minimal additional cost
- System noise is lower due to lower velocity and pressure drop of the constant volume system and no VAV boxes
- Better control of space humidity levels
- More uniform space temperature is achieved
- Occupants are less likely to feel cold drafts

Infrared Thermal image of Chilled Beam Performance



Advantage of Chilled Beams: Improved Indoor Air Quality

- Better than ASHRAE 62 ventilation rates
- No contaminant mixing

Advantage of Chilled Beams: Higher Efficiency

Up to 30% reduction in energy use

- Reduced fan energy
- Ideal application for energy recovery
- Higher design chilled water temperature

Advantage of Chilled Beams: LEED Points

An additional 8 – 10 LEED points can be achieved.

Disadvantages of a Chilled Beam System

- Not well known in our industry. Starting to be utilized more in the States. Proven technology in Europe for last 20 years.

- Higher construction cost compared to VAV.

- Affects traditional ceiling appearance. Chilled beams are larger than traditional ceiling diffusers. Can present challenges for lighting coordination.

- Dew point concerns, building must have good control of humidity to prevent condensation on chilled beam surface.

Case Study: Astra Zeneca – Boston, MA

Astra Zeneca is an international research based pharmaceutical company. They are a European owned company that had been using Chilled Beam technology prior to building in the US. They insisted on installing this system when building here.

- Active Chilled Beams installed in five buildings.
- Chilled Beam system has been in operation since 2000.
- Chilled Beams serve offices, laboratories, cafeteria, and atrium with south facing glass.
- No condensation issues.
- Buildings do not have operable windows.
- 100% Outside Air system provides ventilation requirements.
- Cleaning of Chilled Beams has not been needed in 7 years of operation.
- They are planning a new building that will be using a Chilled Beam system and the latest cost model is showing a $100,000 savings over a conventional VAV system on a multi-million dollar project.

According to Bruce McGregor, Facility Manager, the Chilled Beam system is performing very well, and they are very pleased with it.

AstraZeneca

Case Study: Harvard University – Boston, MA

- Active Chilled Beams are installed in two buildings.
- Chilled Beam system has been in operation since August 2006.
- Chilled Beams serve offices and classrooms.
- One building has operable windows.
- No condensation issues.
- Building is pressurized to reduce infiltration.
- Users were educated on the Chilled Beam system and the importance of keeping windows closed on humid days.
- They are finding that a Chilled Beam system has a lower installed cost than a conventional VAV system.

"This technology is the future of the HVAC industry." Chuck Stronach, Harvard University

Harvard University

Sustainability Principles

"Harvard University is committed to developing and maintaining an environment that enhances human health and fosters a transition toward sustainability. Harvard has already used the LEED standard in over 16 unique building projects."

Harvard Green Campus Initiative
www.greencampus.harvard.edu

Chilled Beams

What is the Financial Feasibility of Chilled Beams?

Assumption

Chilled Beam systems are typically more expensive than other conventional terminal units such as VAV systems.

To test our assumption, we are going to review:

- Cost Considerations
- Case Study – Viterbo University, La Crosse, WI
- Viterbo – Cost Estimate Summary
- Viterbo – Cost Saving Measures
- Conclusions
- Questions

Cost Considerations

- Construction Costs
  - HVAC
  - Electrical
  - General Construction
- Operating Costs
- Maintenance Costs
- Life-Cycle Cost – of a Building

HVAC Cost Increase

- Chilled beam terminal unit costs are higher as more units are generally required
- Chilled water piping costs are higher to distribute chilled water to the beams
- Insulation costs may be higher to insulate the piping (Depends on dew point requirements)

HVAC Cost Decrease

- Smaller central air handling unit sizing (About 65% less than an “All Air” system)
- Using 100% outdoor air to the chilled beams reduces the supply and return air ductwork sizing required
- For the same level of control, chilled beam controls are less expensive (Only simple zone valves required)
- Lower balancing costs (less and easier adjustments to make)

Electrical Cost Increase

- Connected pump horsepower is typically somewhat higher related to the lower water temperature rise (typically 4-6°) used in the secondary water loop serving the chilled beams
- Lower ΔT = Higher GPM = Higher pump motor horsepower

Electrical Cost Decrease

- Reduced Electrical Infrastructure:

  Lower kW/ton required by chiller to produce warmer average chilled water supply temperatures (In general, installed refrigeration tonnage remains the same, but chiller efficiency improves … a lower connected electrical load)

- Reduced Electrical Infrastructure

  Although connected pump motor horsepower is typically higher, this is more than offset by the connected fan motor horsepower

- Above changes should result in reduced electrical infrastructure costs

General Construction Costs

Decreased Costs:

(By lower floor-to-floor heights)

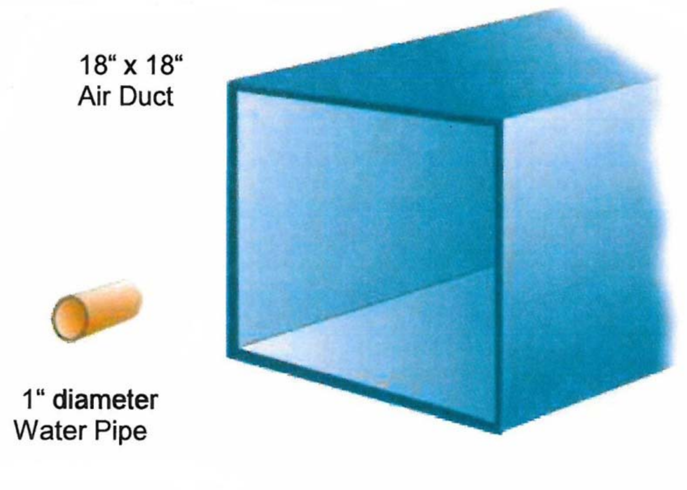
- Structural steel
- Masonry
- Fire-proofing
- Steel studs
- Air barrier
- Insulation
- Exterior caulking
- Curtain wall
- Stairs
- Drywall
- Elevators
- Smaller shafts required, resulting in more usable square footage

General Construction Costs – Ceiling Tiles

- Less Ceiling Tile Required

Operating Costs

- Although total pump energy is generally somewhat higher, this is more than offset by the reduction in fan energy
- A one inch diameter water pipe can transport the same cooling energy as an 18 inch square air duct

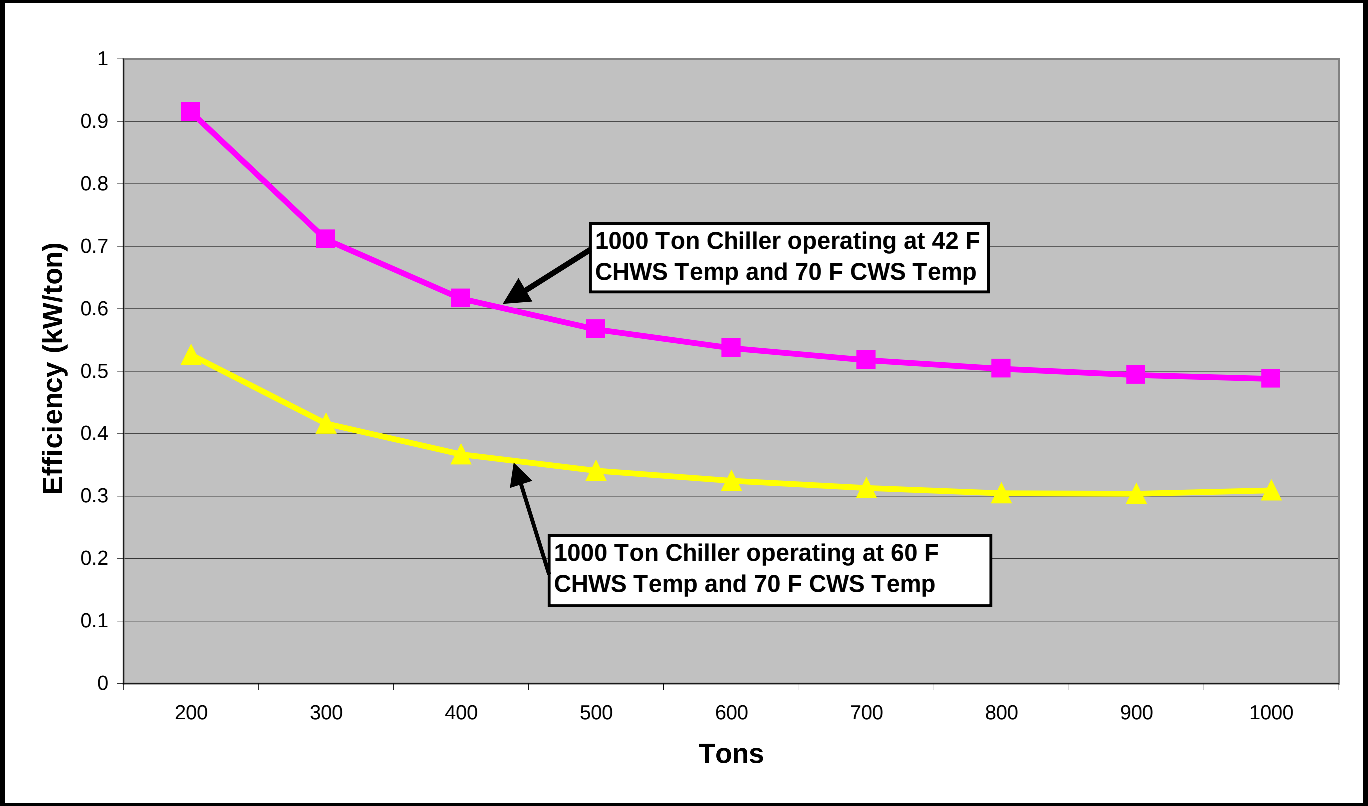


Cooling Energy Transport
Economies of Air and Water

Operating Costs

- Depending on system design, kW/ton is improved by utilizing relatively warmer water temperatures through the chilled beams.
- Higher chilled water temperatures used by chilled beams may allow chiller efficiencies to increase by as much as 35%

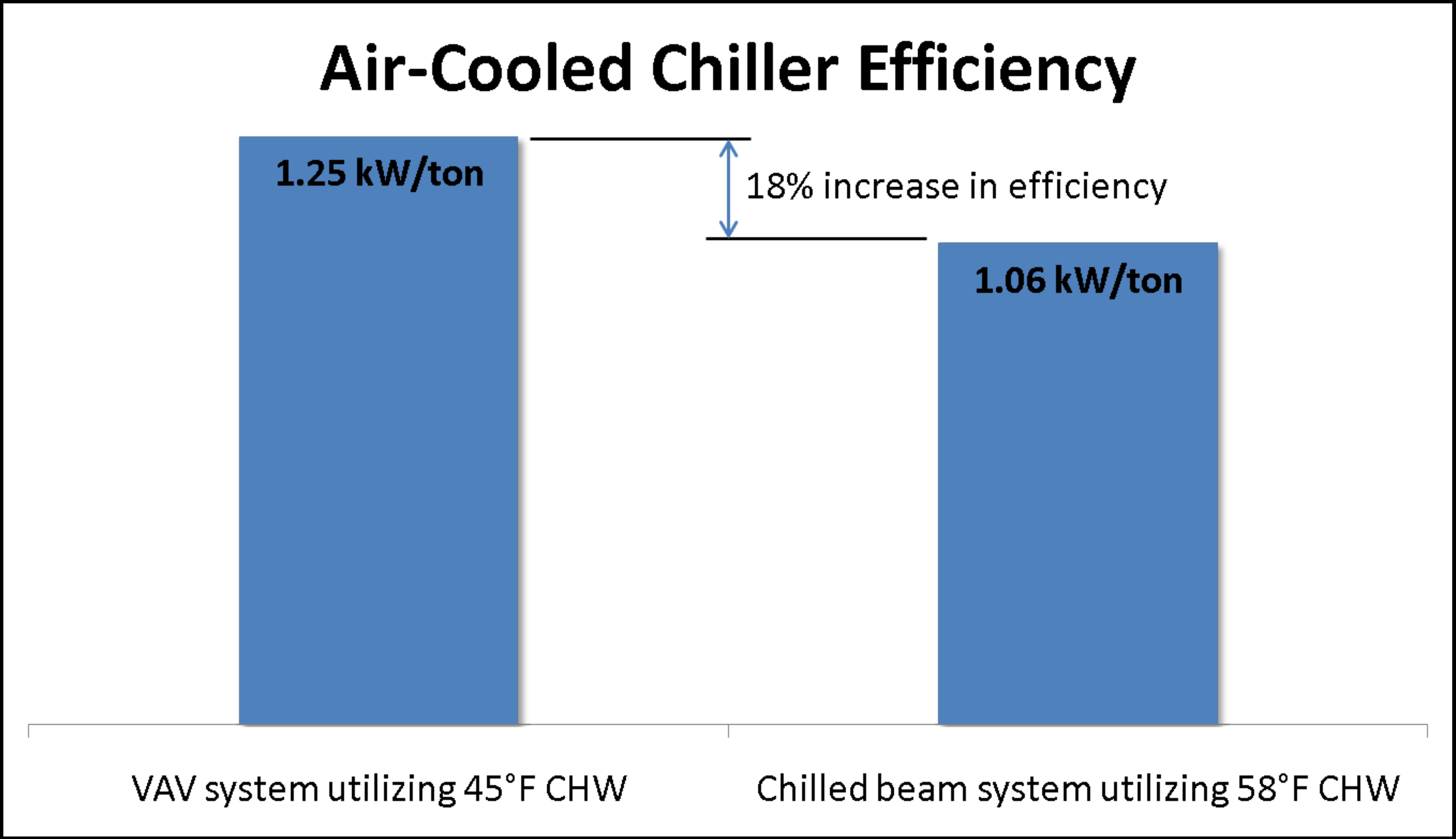
Operating Costs



Comparison of low temperature and medium temperature water-cooled chillers

Note: A medium temperature loop also greatly expands the potential for free cooling

Operating Costs



Maintenance Costs

- Chilled beams have no moving parts and require no regular maintenance

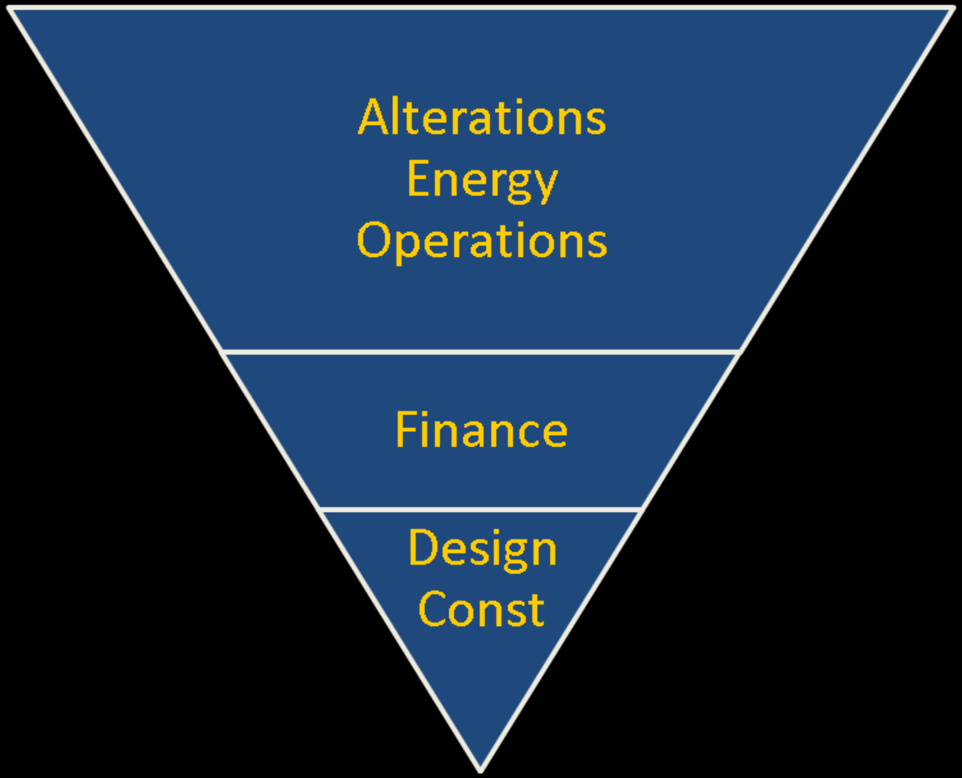
Maintenance Costs

	Fan Coil Unit	Active Chilled Beam
Filter Changes:		
Frequency	Twice Yearly	N/A
Cost per Change:	$30	
Cost over Lifetime (20 years)	$1,200	$0
Clean Coil and Condensate System:		
Frequency	Twice Yearly	Every 4 years
Cost per Change:	$30	$30
Cost over Lifetime (20 years)	$1,200	$150
Fan Motor Replacement:		
Frequency	Once during life	N/A
Cost per Change:	$400	
Cost over Lifetime (20 years)	$400	$0
Life Cycle (20 years) maintenance cost:	**$2,800**	**$150**

Source: REHVA Chilled Beam Application Guidebook (2004)

Life Cycle Costs – Of a Building

- 75% Alterations, Energy & Operations
- 14% Finance
- 11% Design & Construction



Taken from LEED New Construction Version 2.2 Study Guide

Case Study: Viterbo University

Viterbo University – La Crosse, WI

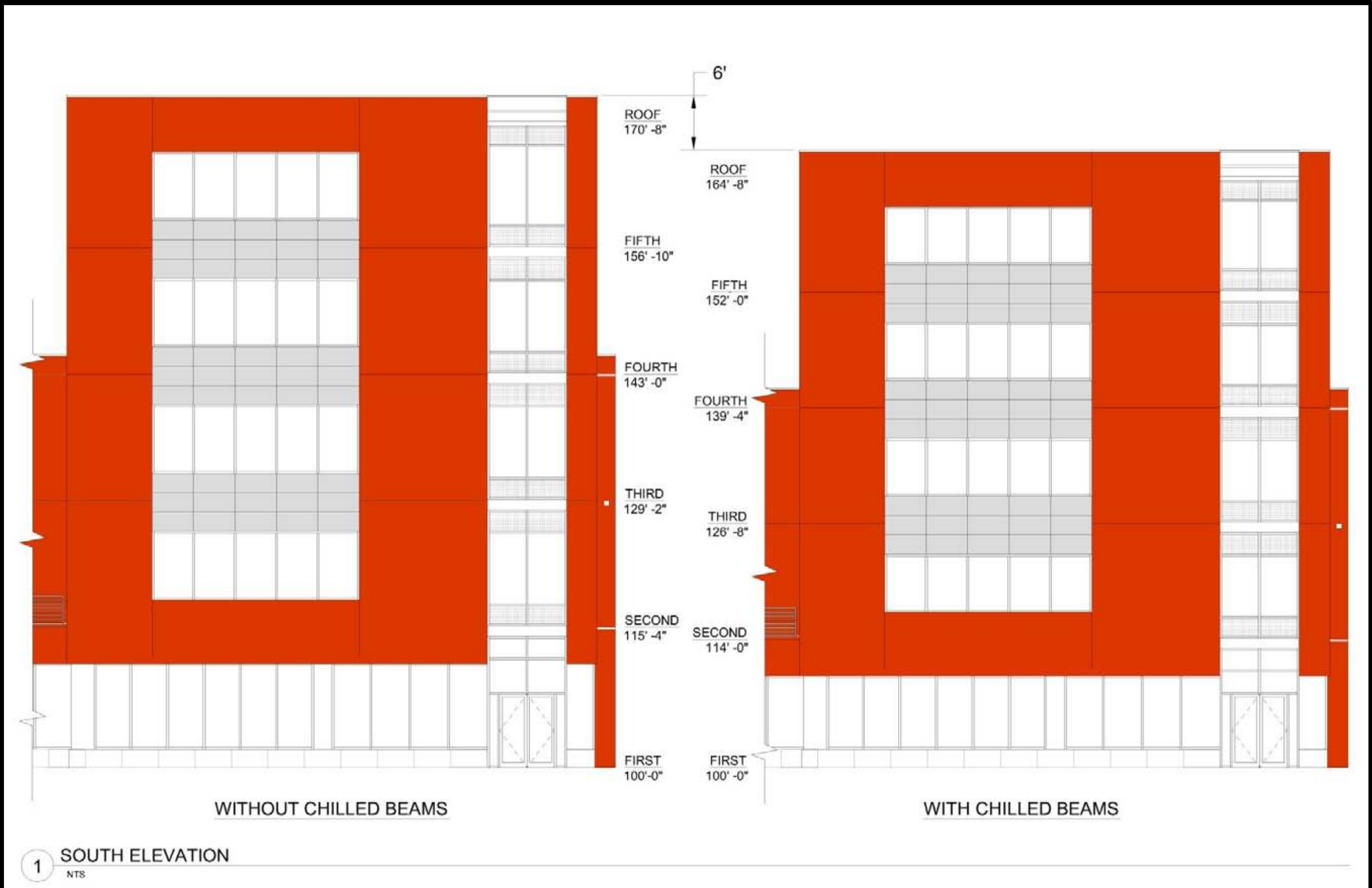
- North end – Basement + 3 levels
- South end – Basement + 5 levels
- 65,000 ft²

Case Study: Viterbo University

By lowering floor-to-floor heights on average by 10” – 14”…

…height of building was reduced by 6 feet!

Case Study: Viterbo University



Case Study: Viterbo University

- City of La Crosse – For every 5’ in height, setback is increased by 1’
- Lowering the building 6’ allowed for more square footage per floor

Viterbo – Cost Estimate Summary

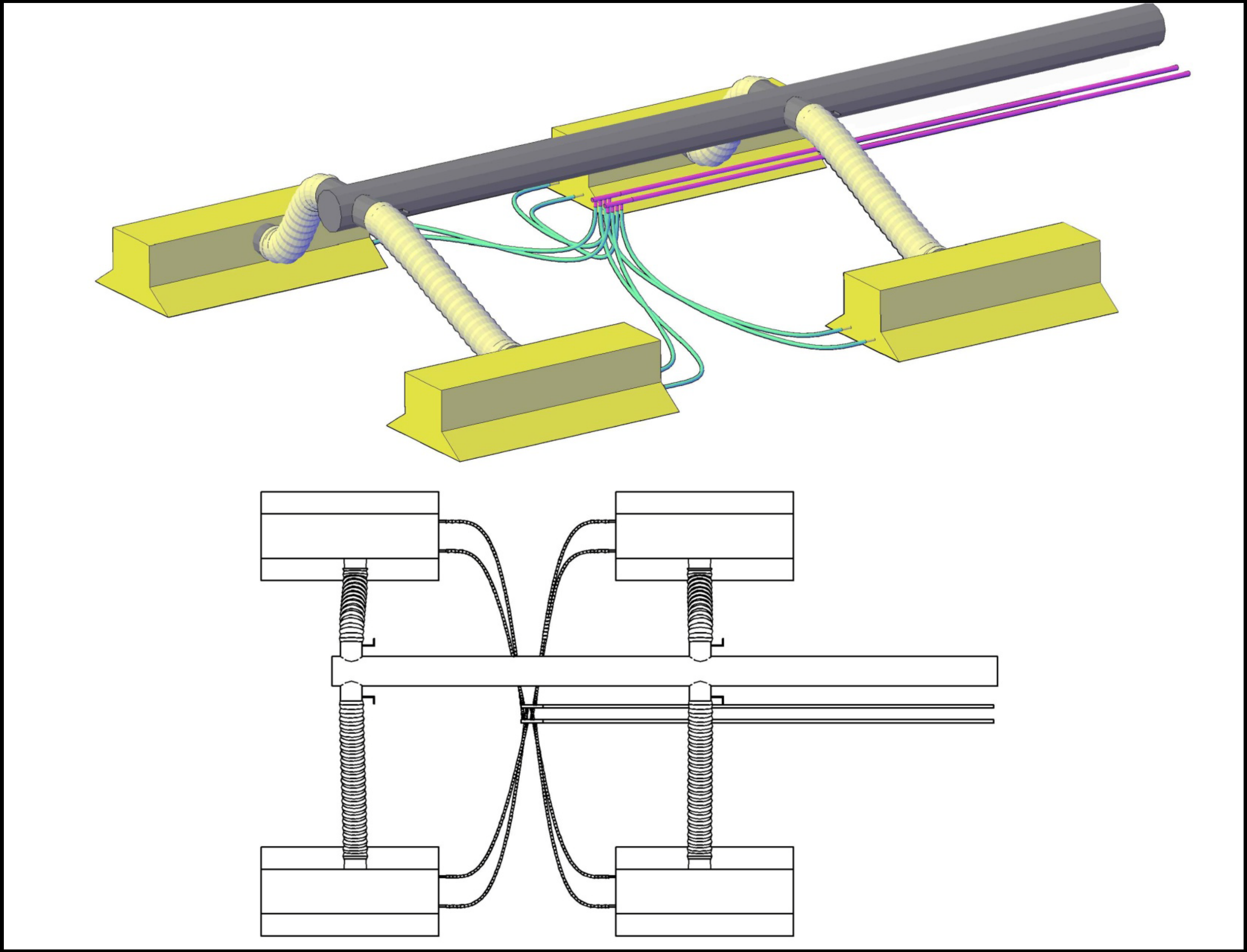
Pricing provided by CD Smith Construction

Structural Steel	$7,200
Masonry (Int/Ext)	$97,692
Fire-Proofing	$600
Steel Studs	$22,824
Air Barrier	$8,787
Insulation	$3,424
Exterior Caulking	$1,522
Curtain Wall	$10,500
Stairs	$2,500
Exterior Drywall	$55,249
Elevators	$5,000
Electrical	$30,000
Total Construction Cost Savings	**$245,298**

Viterbo – Cost Saving Measures

- Total cost add for chilled beams: $300,000
- Through value-engineering changes such as:
  - Reduction in control zones
  - Removal of insulation of chilled water piping on floors
  - Provide 1 energy recovery unit in lieu of 2
  - Provide 2 hot water boilers in lieu of 3
  - Eliminate balance valves through the use of pressure independent control valves
  - Use PEX tubing

Viterbo – Cost Saving Measures



Viterbo – Cost Saving Measures

When will condensation on the coil be of concern?

- 75 F db room design temperature at 50% relative humidity
- 55 dew point temperature
- Theoretically, condensation will form on the coil when the chilled water temperature is 55 F
- Apparent room dew point is 2-3 F lower due to insulating effect of air film on coil fins
- In reality, at this room design condensation will not begin to form until the water temperature is 52-53 F

Viterbo – Cost Saving Measures

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®

Viterbo – Cost Saving Measure

Focus On Energy – Equipment Incentives

1. Modulating hot water boiler w/≥85% efficiency w/ bonus $0.10/MBh for each 1% thermal efficiency greater than 85%		$2025
2. Energy Recovery Ventilator	$1.25/cfm	$25,000
3. Air-Cooled Electric Chiller	$20/ton	3,600
4. Variable Frequency Drives	$50/hp	$12,500
5. 3-Phase Electric Motors	$3-$5/hp	$630
6. Chilled Beam	Custom	???
Total Incentives		$43,755

focus on energy
The power is within you.

Viterbo – Cost Saving Measures

Final construction cost determination to include chilled beams was valued at NO ADDITIONAL COST

Conclusions

- The HVAC costs associated with chilled beams are more expensive than other conventional systems
- Depending on the type of building, the general construction costs utilizing chilled beams can be LESS

Conclusions

- The operating costs associated with chilled beam systems is generally less
- The maintenance costs associated with chilled beam system is generally less

Conclusions

- Our original assumption may not be correct.
- The “Total” overall construction costs may not be any higher for chilled beam systems
- To determine the “True” financial feasibility of chilled beams, the total life-cycle costs for each of the proposed systems should be compared

Energy Savings Analysis - Chilled Beams Over VAV

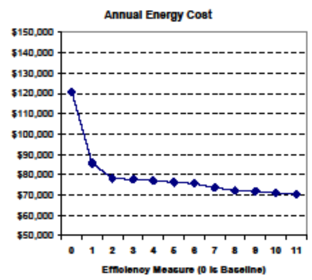
WHA Clinic
Focus on Energy New Construction Incentive Program
Summary Report
Prepared by Scott Hackel and Scott Schuetter 10/5/2009

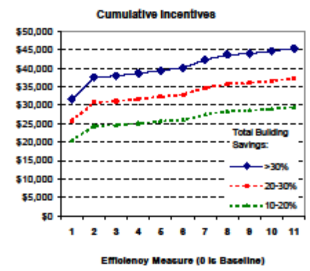
ENERGY CENTER OF WISCONSIN
455 Science Drive, Suite 200
Madison, WI 53711
Phone: 608.238.4601

Streel framed wall construction, veneer, metal deck roof
Building area (sq. ft.): 62,000

The FOE baseline is modeled assuming a VAV system with HW reheat throughout the building. The next scenario models a switch to a chilled beam system (served by 0.94 kW/ton chiller at elevated - 60°F - CHW conditions), with a dedicated outdoor air system served by dual-wheel energy recovery. Next, condensing boilers are added to the system. This improved system is then modeled with several different architectural, lighting, and other improvements.

		Energy Savings		Peak Tons	Incentive		
				Savings	With total building savings of:		
	Energy Efficiency Measure	$ (annual)	%	%	10-20%	20-30%	>30%
0	FOE Baseline	-	-	-	-	-	-
1	Chilled beams w/ERU	$35,109	29.1%	N/A	$20,405	$25,799	$31,585
2	Condensing boilers	$7,491	6.2%	N/A	$3,956	$4,945	$5,935
3	Improved wall	$423	0.4%	1.0%	$257	$324	$393
4	Improved roof	$559	0.5%	3.7%	$472	$601	$746
5	Improved windows	$932	0.8%	0.0%	$478	$594	$705
6	Ext. solar shading	$539	0.4%	3.3%	$467	$596	$743
7	Automatic daylight ctrls.	$2,056	1.7%	0.9%	$1,399	$1,773	$2,178
8	Efficient lighting design	$1,377	1.1%	1.7%	$914	$1,154	$1,408
9	Demand control vent.	$393	0.3%	0.0%	$176	$221	$269
10	High eff. DHW heater	$871	0.7%	0.0%	$464	$581	$697
11	Bi-level stairwell lighting	$734	0.6%	0.0%	$481	$603	$727
	Totals (1-11)	**$50,483**	**41.8%**	**11%**	**$29,469**	**$37,191**	**$45,385**





Notes:
1. Incentive level (10,20,30%) depends on the total accumulated %-savings from all measures installed;
Whichever level is reached is used to determine the incentive for all measures chosen.
2. These are estimated incentives, subject to approval from Focus on Energy.

Energy Savings Analysis – Chilled Beams Over VAV
Case Study: WHA Clinic

- $50,483 Total Annual Savings
- Almost $1/SF savings
- $35,109 Savings due to Chilled Beams and Energy Recovery
- 41.8% Total annual Savings
- 29.1% Savings Due to Chilled Beams and Energy Recovery
- Greater Than 30% Savings Incentive
- $45,385 Overall Incentive
- $31,585 Incentive Due to Chilled Beams and Energy Recovery

Questions?