Chilled Beams

By Ed Fruth, Regional Sales Manager, Northeast

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Audio

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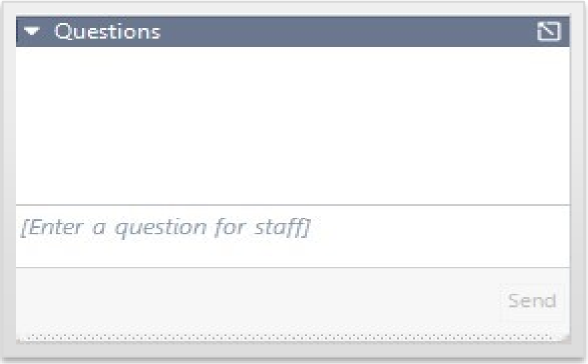
Questions

Questions can be submitted at anytime during today's presentation.



Use the question function on your tool bar and we will moderate and answer your question at the end of the presentation.

Chilled Beams

Learning Objectives

By the end of this course, participants will understand:

1. What are the three types of Chilled Beams
2. Benefits of Chilled Beam Designs
3. Chilled Beam System Design Basics
4. Chilled Beam Selection and Software Tools

Chilled Beams

Basics of Chilled Beams

Chilled Beams

Basics of Chilled Beams

- What is a Chilled Beam?
  - A SENSIBLE ONLY device that uses chilled or heated water supplied above the room dew point to cool or heat the space in which it is installed.

Chilled Beams

Basics of Chilled Beams

- Why Chilled Beams?

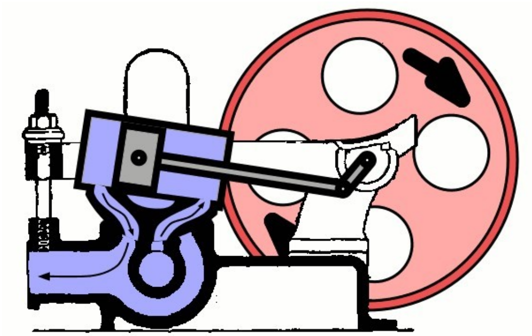
Chilled Beams

Basics of Chilled Beams

- Potential for:
  - Reduced Fan Capacity
  - Reduced Cooling Capacity
  - Reduced Ductwork Sizing
  - Reduced Noise
  - Reduced Reheat Potential
  - Reduced Maintenance in the Space
  - Reduce Duct Static at the Fan and in the Space
  - Improved Chiller Efficiencies

Basics of Chilled Beams

Basic Laws of Thermal Dynamic's



Motors and Pumps

Little to no Maintenance

Chilled Beams

Basics – Cooling Capacity Comparison

- Water Side Design
  - Water heat transfer vs. Air heat transfer
    - Chilled beams decouple airside and waterside
      - Min. 50-50 split between and airside and waterside cooling [3]
    - On Mass Flow Rate Basis
      - 1 lbs of chilled water (6° Δt) transports 4x more cooling energy than 1 lbs of air (20 ° Δt)
    - Transportation Energy
      - Water has 3,500 times more volumetric heat capacity than air [3]
      - Transportation of a ton of cooling by air requires 7 times more than chilled water [3]

19.2 Heat Transfer Differences Between Air–Air and Air-Water Systems, page 1061

Chilled Beams

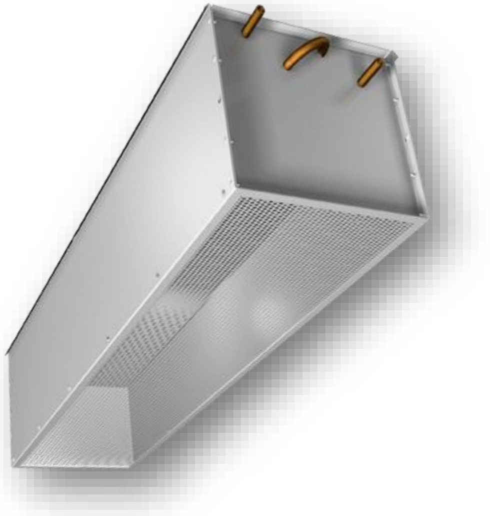
Products Overview

- Three types of Chilled Beams

Overhead Active Chilled Beams

Floor Mounted Chilled Beams

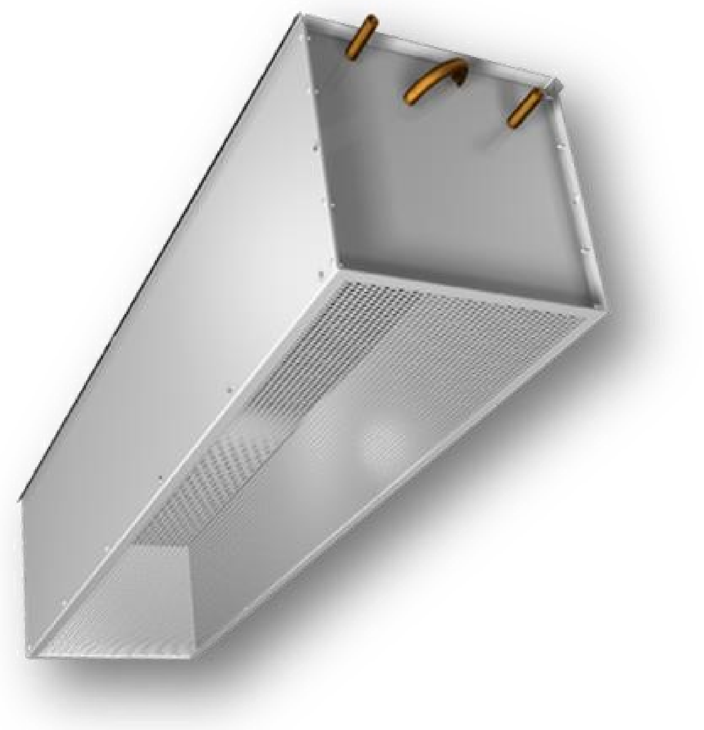
Passive Chilled Beams



Chilled Beams

Passive Chilled Beams

Passive Chilled Beams



Chilled Beams

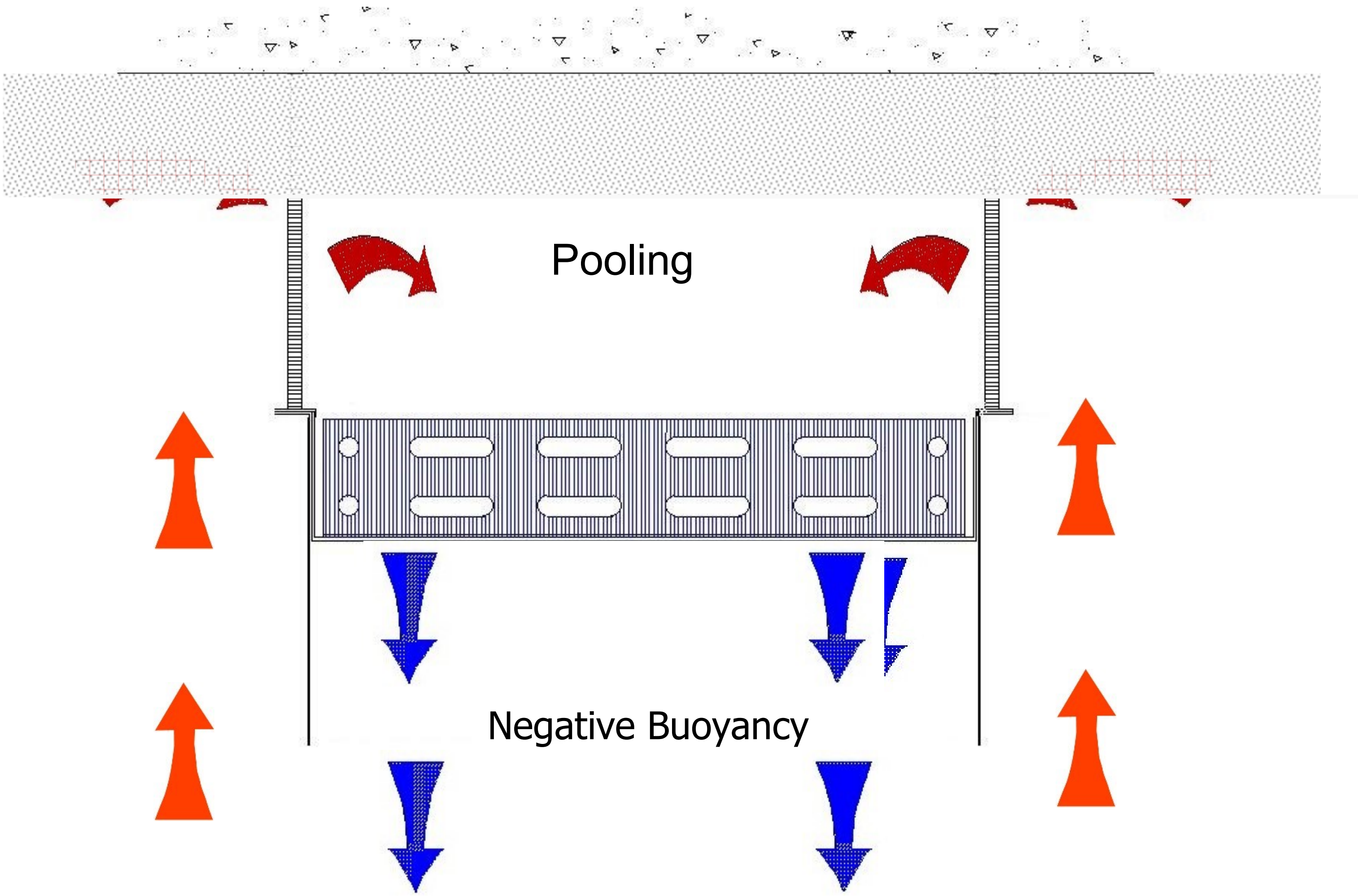
Passive Chilled Beams

Roughly 300-400 BTU's a Linear Foot

- Passive Chilled Beams are Conductive Cooling Coils mounted in a box.
- Chilled water supply above room dew point
- Wide fin spacing
- No Ventilation or Latent Capacity
- No moving parts
- No direction of Flow

Chilled Beams

Passive Chilled Beams



Chilled Beams

Passive Chilled Beams

- Passive chilled beams are not radiant devices, they primarily convective devices (about 85%)
- Passive beams are not efficient for heating
- Passive chilled beams require a separate air supply that takes care of:
  - Space Ventilation Requirements
  - Space Latent Requirement

Chilled Beams

Active Chilled Beams – Chilled Beams Styles

Active Chilled Beam Linear (ACBL)

Active Chilled Beam Cabinet (ACBC)

Passive Chilled Beam Linear (PCBL)

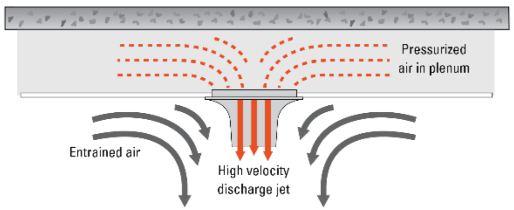
Active Chilled Beam Modular (ACBM)

Active Chilled Beam Recessed (ACBR)

Chilled Beams

Active Chilled Beams

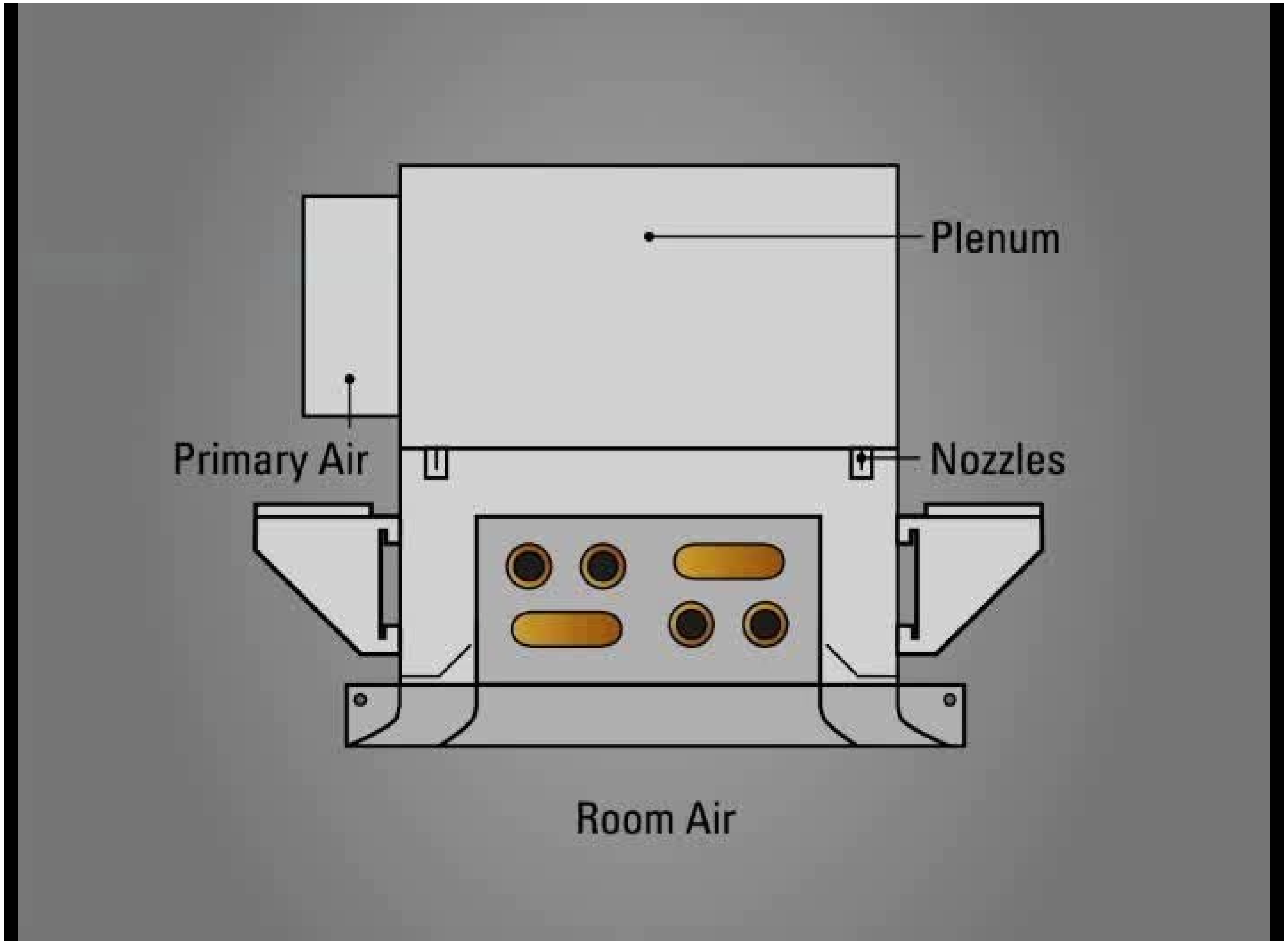
Nozzles



- Tempered air is supplied from an air handler to the chilled beam, providing the ventilation and latent requirements for the space.
- The coil, provides hot or cold water for cooling or heating.
- The nozzles provide the power to induce air from the space through the coil

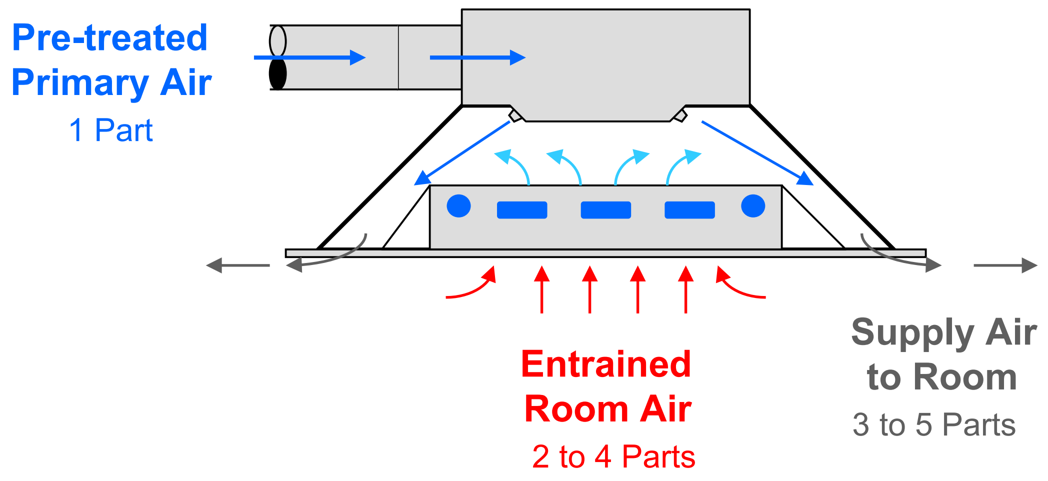
Chilled Beams

Active Chilled Beams – How They Work



Chilled Beams

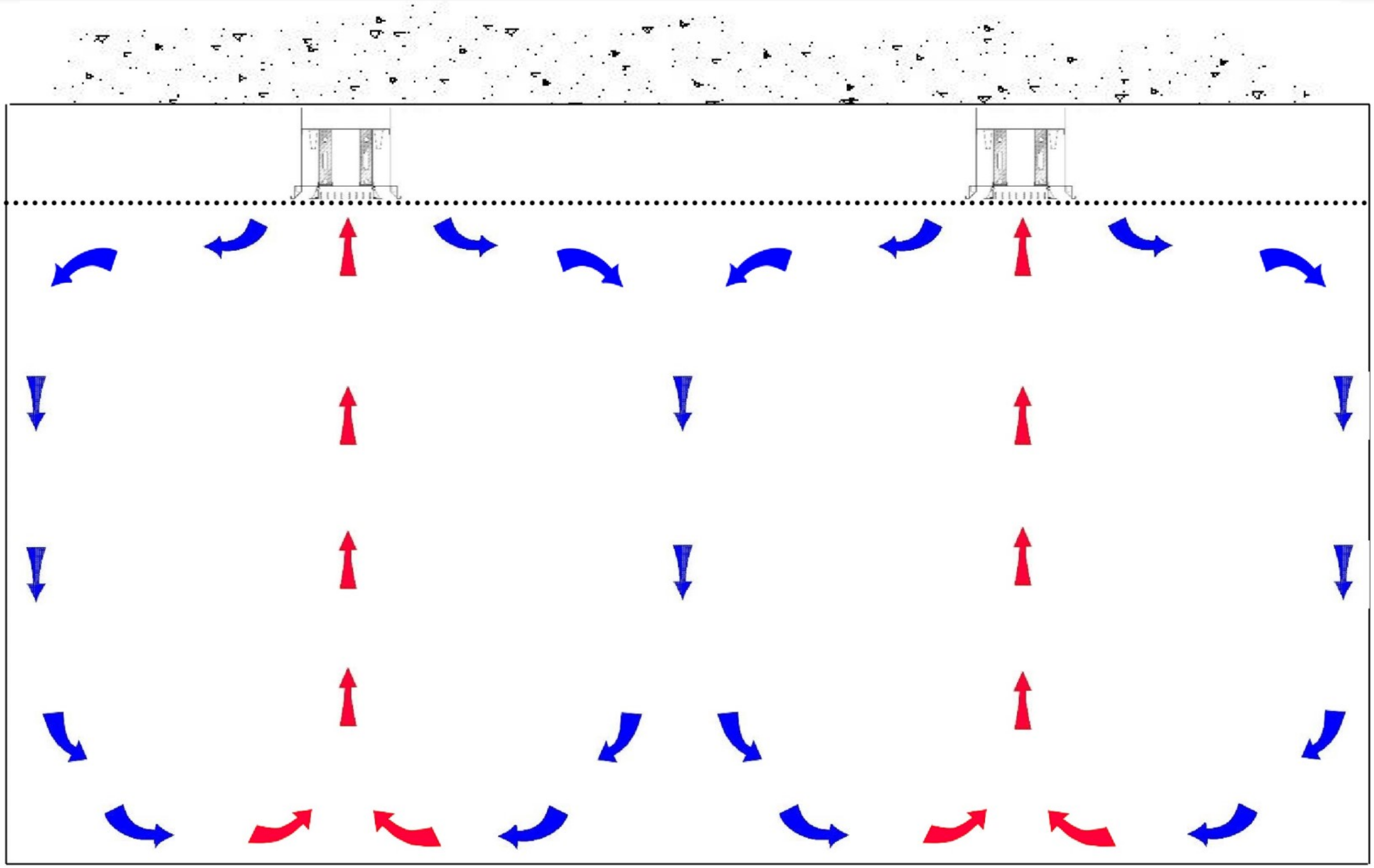
Active Chilled Beams



- Combines sensible, latent cooling and ventilation
- Room air induction ratio determined by nozzle size
- Modular design for ceiling integration
- .4 - .7 inches of water / 1200 – 3000 fpm
- 5 to 15°F warmer than that delivered with all air systems

Chilled Beams

Active Chilled Beams – Air Distribution Pattern



The resultant space air diffusion is similar to that affected by a ceiling slot diffuser, that is a fully mixed system. The temperature of the air in the occupied zone, at the return and at the induction face of the beam are all, thus, similar.

Chilled Beams

Active Chilled Beams

- The induction of the air through the coil significantly enhances the cooling capacity of the unit.
- Very quiet 15NC – 35NC
- Roughly 1000 BTUs a Linear Foot

- Air and water systems combined into single thermal diffuser
- Primary Air delivered at conventional (54ºF to 58ºF) temperatures/ thru induction nozzles
- Chilled water delivered between 55ºF and 58ºF
- Designed for integration into acoustical ceiling system or surface mount/exposed ceiling.
- Two pipe – four pipe
- One way, two way, four way
- Heating and cooling option
- 24” and 12” widths

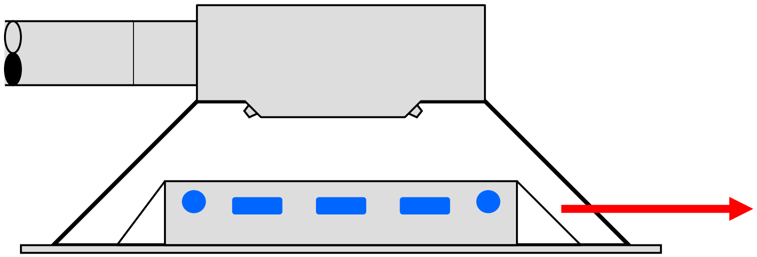
Chilled Beams

Active Chilled Beams

Primary Air from AHU

Reduced 60 to 80%

Based on VAV/Mixed Air System



60 to 80% of Sensible
Heat Removed by Water

- Active beams are capable of extracting 60 to 80% of the space sensible gains by means of their chilled water circuit, thereby reducing the primary air contribution to the space sensible cooling proportionally.
- Good Chilled Beam designs are roughly .2 to .4 CFM a square foot verse 1 to 1.2 CFM a square foot for traditional VAV designs.

Chilled Beams

Active Chilled Beams - Benefits

Chilled Beams

Active Chilled Beams - Benefits

- Increased Comfort
  - 100% outside air
  - Less noise
  - Better mixing in the space
  - Higher discharge air temperatures

Potentially reduce or eliminate reheat [2][3]

Warmer discharge air temps, modulation on waterside

Cooling and reheating can account for 20% of annual HVAC Costs [2]


LABORATORIES FOR THE 21ST CENTURY: BEST PRACTICE GUIDE

CHILLED BEAMS IN LABORATORIES: KEY STRATEGIES TO ENSURE EFFECTIVE DESIGN, CONSTRUCTION, AND OPERATION

Introduction

EPA United States Environmental Protection Agency

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Federal Energy Management Program

Chilled Beams

Active Chilled Beams - Benefits

- Dual Temperature Chiller Plant [5]

TABLE 1 Effect of chilled water temperature on chiller performance.

STANDARD 90.1-2016 STANDARD CONDITIONS		STANDARD 90.1-2016 55°F CHILLED WATER		STANDARD 90.1-2016 42°F CHILLED WATER	
FL	IPLV	FL_{adj}	PLV_{adj}	FL_{adj}	PLV_{adj}
KW/TON					
0.585	0.390	0.463	0.309	0.611	0.407

  - Lower energy use per ton of cooling
  - Higher chiller COP

Chilled Beams

Active Chilled Beams - Benefits

- Tahoe Case Study [2]
  - Reduction of size of air handler & ductwork
  - Eliminate reheat
  - Floor to ceiling height reduced between 6-18in.

	Chilled Beams	**Standard System Design**
OA Air Handler Sizing	18,000 cfm	27,000 cfm
Ductwork	30,000 lb	37,500 lb
Exhaust Fan Capacity	18,000 cfm	27,000 cfm
Cooling System Capacity	20 tons	35 tons
Floor to Ceiling Height[1]	10 ft.	9 ft.
Mechanical System Cost[2]	$722,000	$741,000

Notes

1. Floor to floor height kept constant; active chilled beam allowed for ceiling to be raised 1 ft.
2. Laboratory portion of the building is 10,000 sq.ft. or 25% of the building. HVAC costs include laboratory system only.

Source: Rumsey, P.E., P. and Weale, P.E., J. (2006). Chilled Beams in Labs - Eliminating Reheat & Saving Energy on a Budget. ASHRAE Journal, 49, p.25.

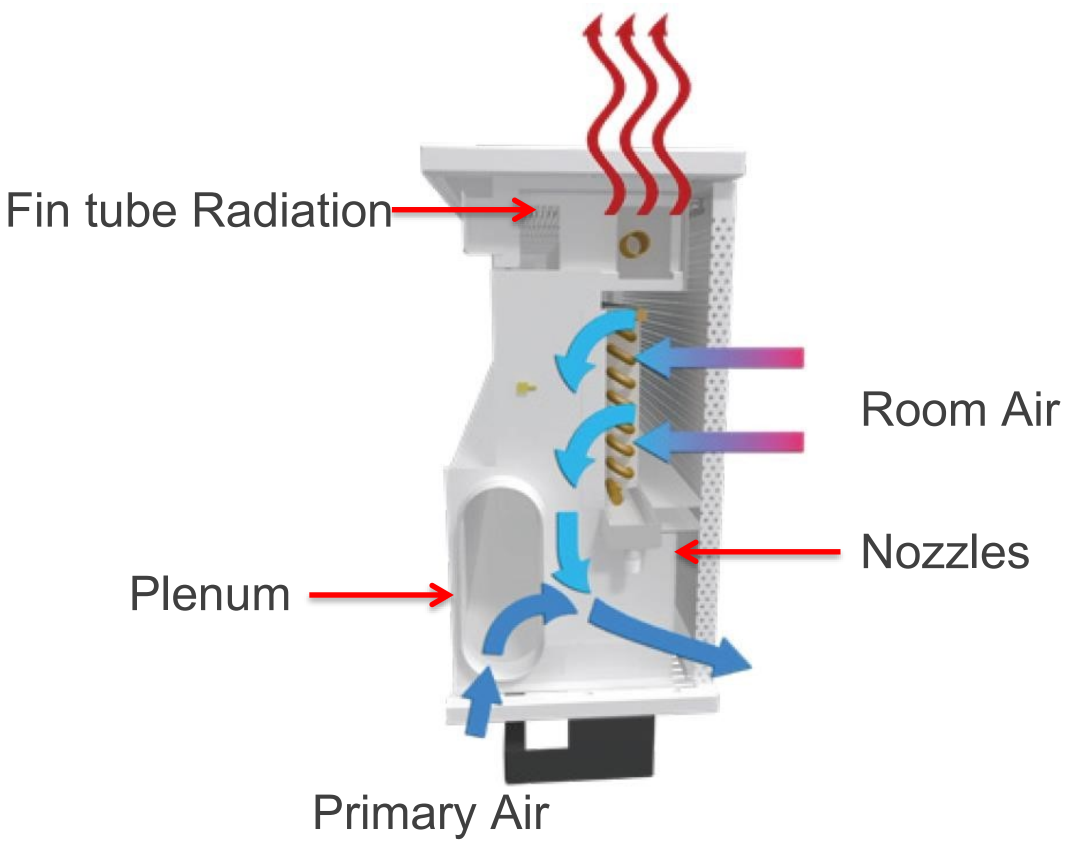
Chilled Beams

Displacement Chilled Beams

For Classroom HVAC Applications

Chilled Beams

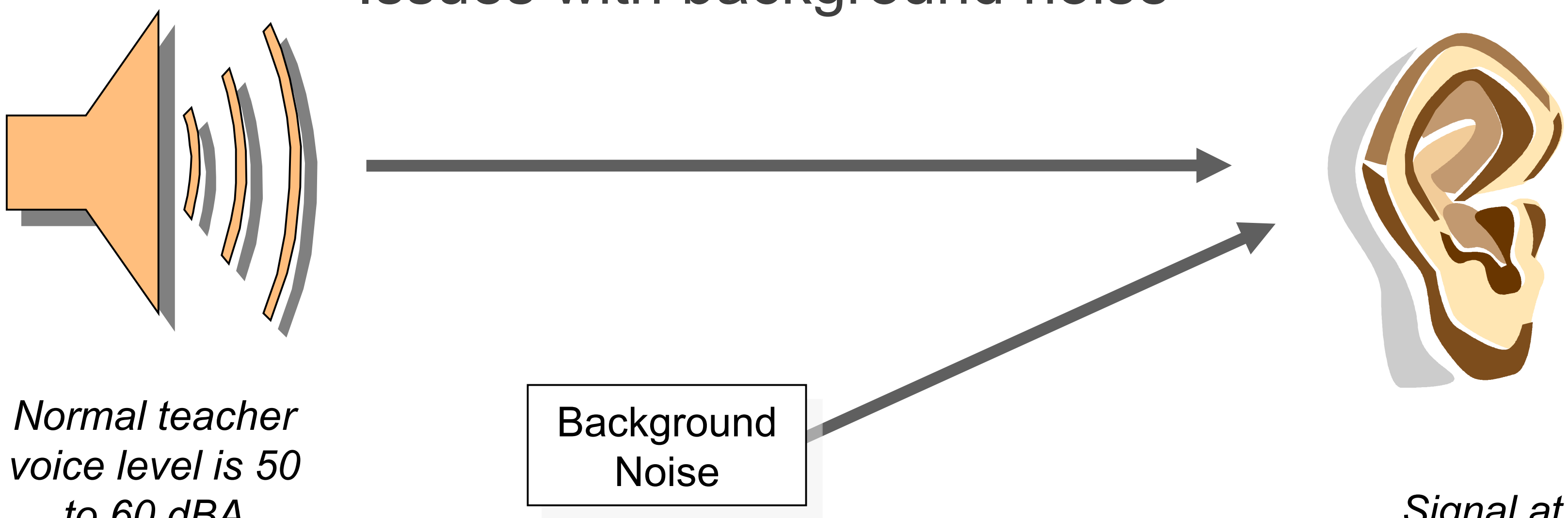
Displacement Chilled Beams



Chilled Beams

Displacement Chilled Beams

Issues with background noise

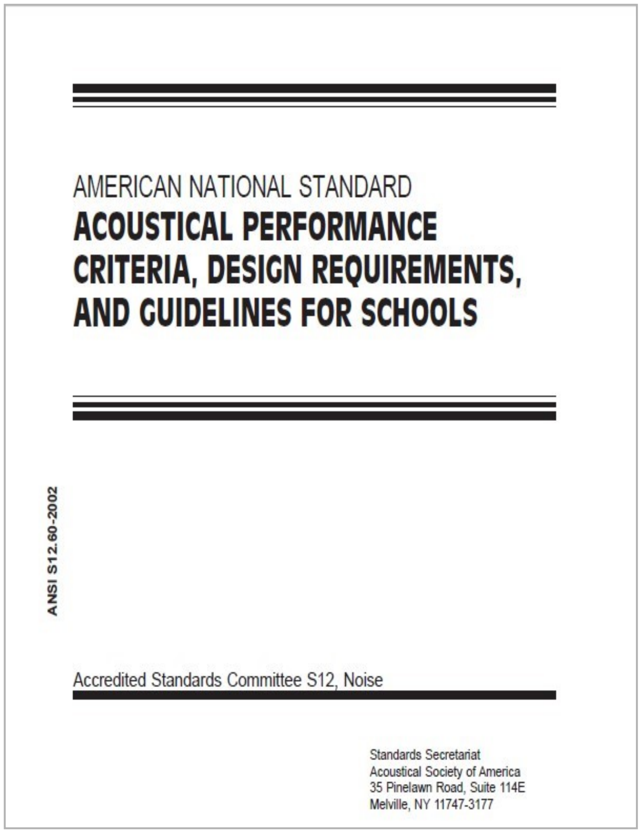


Signal at receiver should be 15 dBA above background

Background noise should not exceed 35 dBA

Chilled Beams

Displacement Chilled Beams


AMERICAN NATIONAL STANDARD

ACOUSTICAL PERFORMANCE CRITERIA, DESIGN REQUIREMENTS, AND GUIDELINES FOR SCHOOLS

ANSI S12.60-2002

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114E
Melville, NY 11747-3177

- ANSI/ASA Standard S12.60
  - Objectives of Standard:
    - Establish SNR that will enable all students to hear teacher speaking at normal voice level
    - Academic improvement
    - Reduction of teacher vocal stress
  - Provisions of Standard
    - Reverberation times of 0.6 seconds
    - Background noise levels ≤ 35dBA in all core learning areas!

Chilled Beams

Displacement Chilled Beams

- "Breathing fresh air is not only critical for keeping students healthy, but also for keeping them alert."

- "Several studies have linked recirculating air and low ventilation rates in classrooms with lower daily attendance & slower speed in completing tasks"

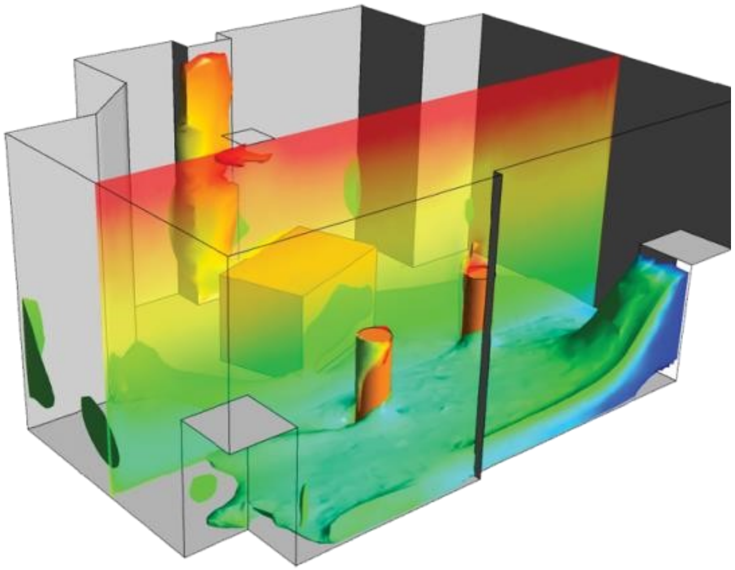
- Children eat, drink, and breathe more per pound of body weight than adults.

Chilled Beams

Displacement Chilled Beams

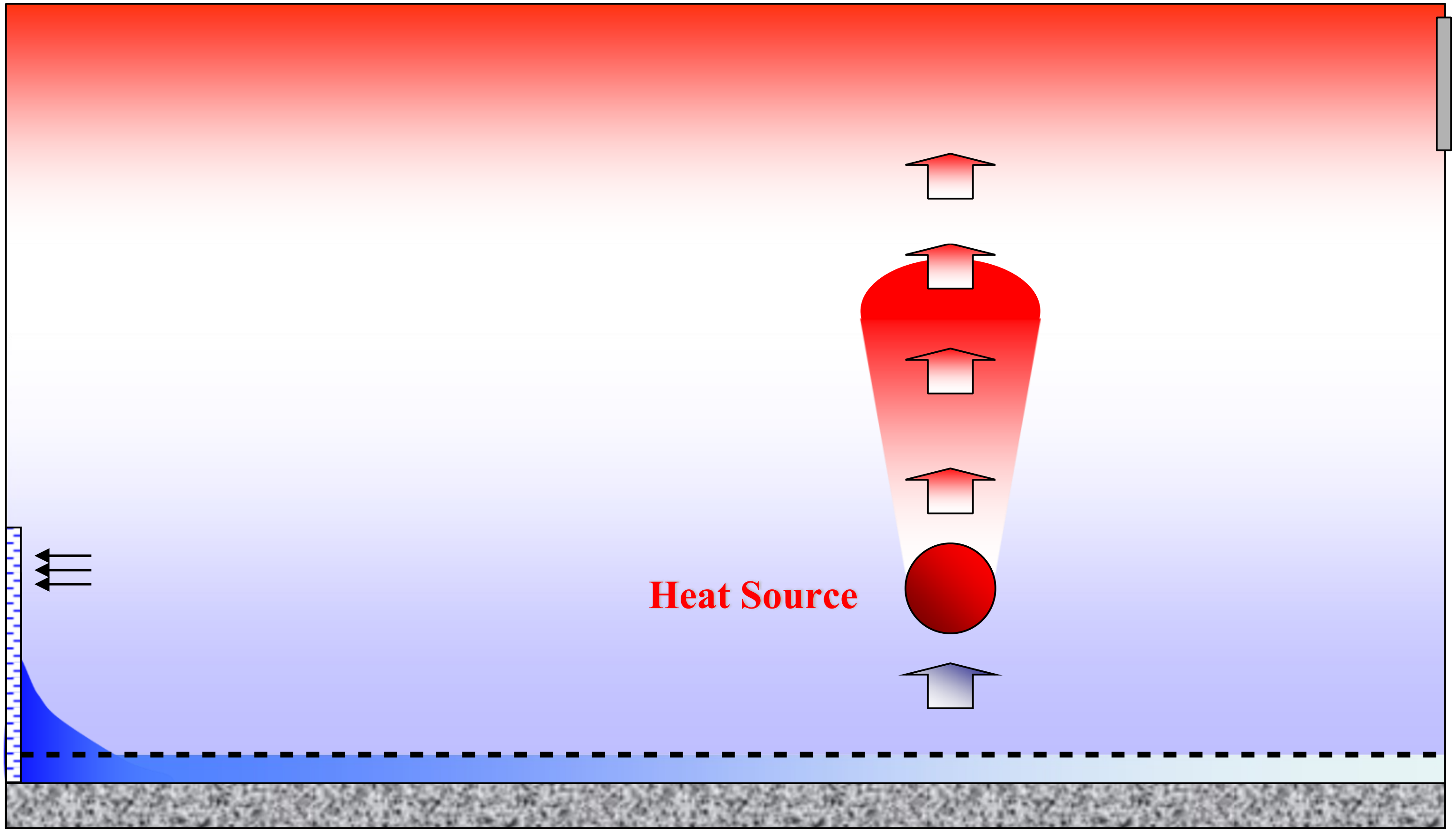
Displacement Ventilation

- 65-68ºF supply air
- Low velocity
- No mixing in space
- Heat sources drive air motion
- Stratified heat, contaminants
- Only conditions the occupied zone
- High level return



Chilled Beams

Displacement Chilled Beams



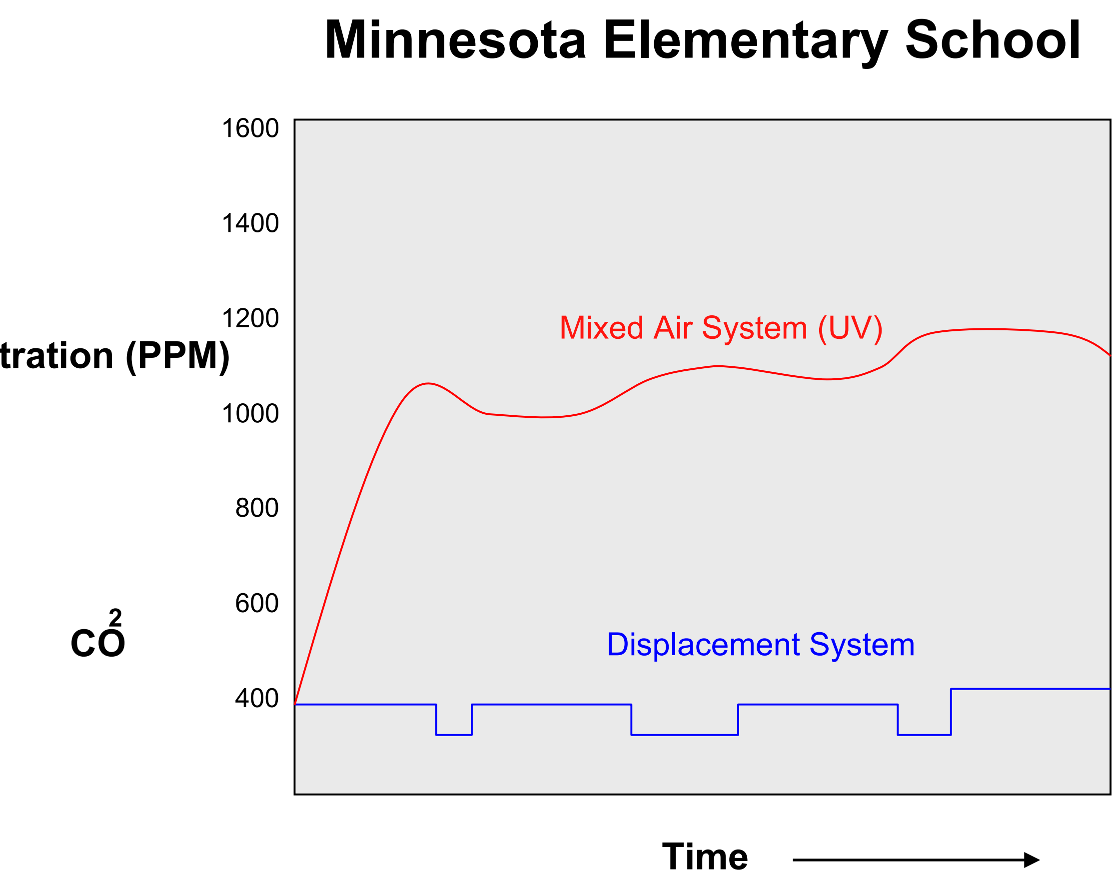
Chilled Beams

Displacement Chilled Beams

- Heat plumes drive contaminants upwards

Chilled Beams

Displacement Chilled Beams



- Identical classrooms
- Tests conducted over two week period
- CO_2 concentration at six foot level monitored
  - Mixed system: 1200 PPM
  - DV system: 400 PPM
- 20% reduction in CO levels produced 15% improvement in student performance

Source: Technical University of Denmark (Indoor Air 2005)

Chilled Beams

Displacement Chilled Beams

Chilled Beams

Installation Examples

Chilled Beams

Displacement Chilled Beams - Advantages

- Acoustic levels compliant with ANSI S12.60-2009
- Cleaner Air in the Space - DOAS
- Cleaner Air - Displacement Ventilation of Classroom
- Low CO_2 levels
- All the Benefits of Traditional Chilled Beam systems
- Specifically designed for K-12 applications
  – Rugged construction
  – Vertical coil affords employment of condensate tray
  – Variety of accessories/options to facilitate installation

- Ideal for both new construction and retrofit

Chilled Beams

Applications

Chilled Beams

Chilled Beam Applications

Where to Use Them

- Anywhere you can control the indoor humidity
  - Laboratories
  - Office buildings
  - Call centers
  - Educational facilities
  - Government facilities
  - Healthcare facilities
- Ideal Applications
  - Spaces with critical ventilation requirements
  - Spaces where sensible cooling dominates

Where Not to Use Them

- Spaces where indoor humidity **cannot** be controlled
  - Kitchen areas
  - Bathrooms
  - Other areas with low sensible heat ratios

Use With Caution

- Rooms with operable windows
- Retrofit of leaky buildings
- Entrance lobbies/atriums

19.3 When to Use Active and Passive Beams

Chilled Beams

ACBL

CHOP

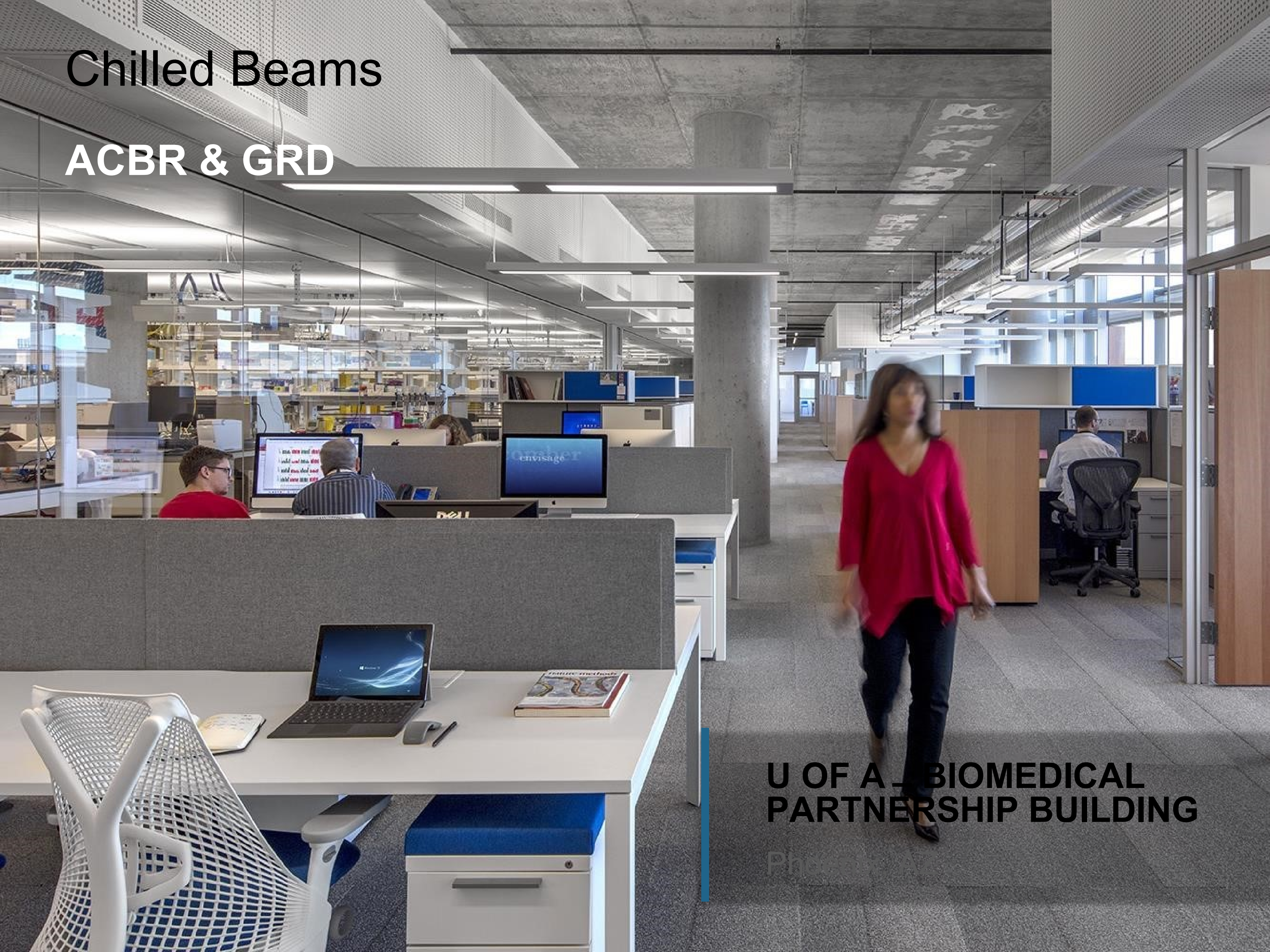
Philadelphia

Chilled Beams

Model Types

Chilled Beams

ACBR & GRD



U OF A _ BIOMEDICAL PARTNERSHIP BUILDING

Chilled Beams

Model Types

WINCHESTER HIGH SCHOOL

Winchester, MA

Chilled Beams

ACBL – Slimline Option

Laboratories

NOVARTIS

Boston, MA

MEMORIAL HOSPITAL

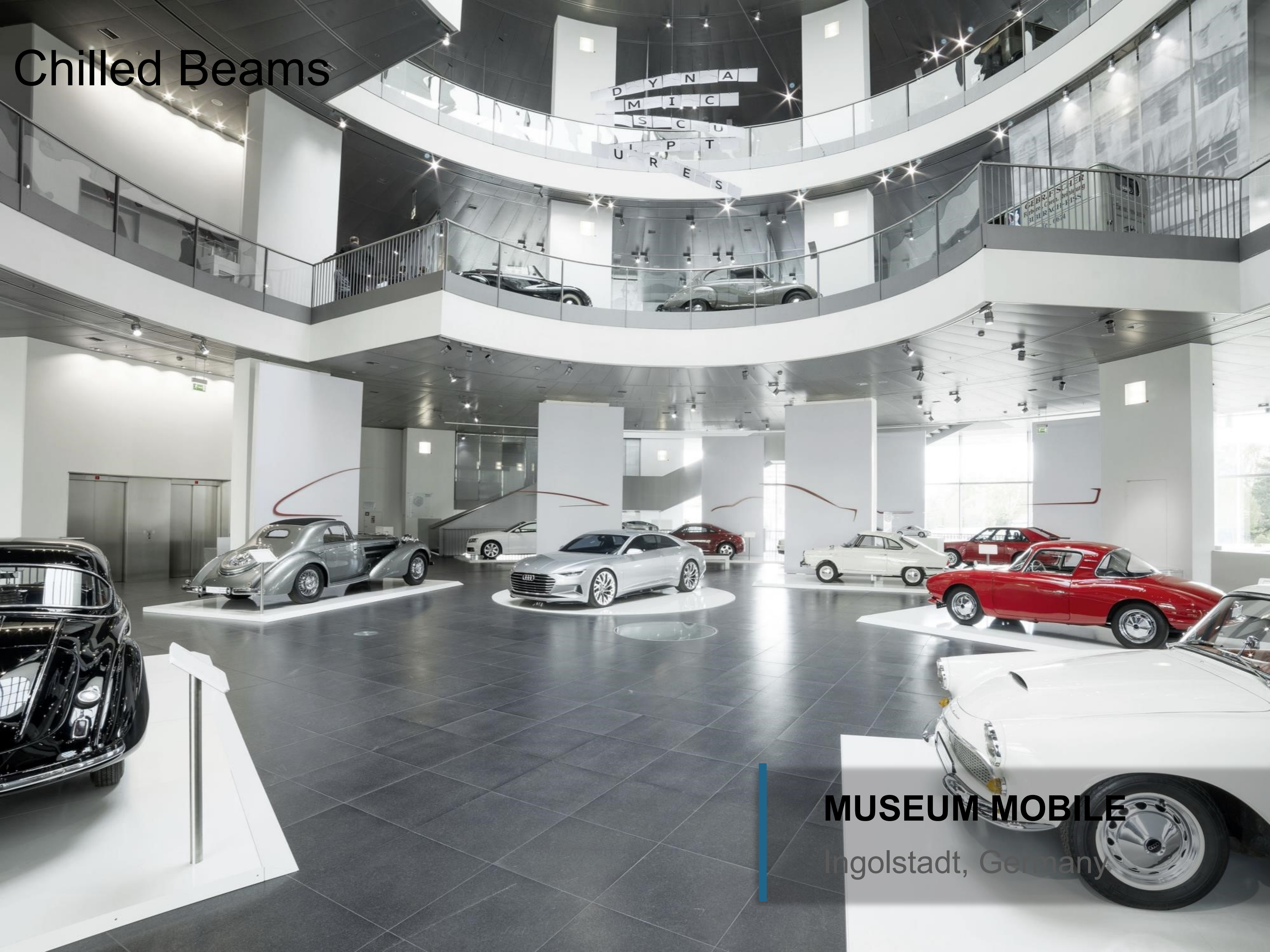
Jasper, IN

Tertiary Education

UNIVERSITY OF OREGON

Eugene, OR

Chilled Beams



MUSEUM MOBILE

Ingolstadt, Germany

Chilled Beams

Chilled Beam System Design

19.9 Active Beam Selection and Design Procedures

Chilled Beams

Chilled Beam System Design

- So what do we need to design a Chilled Beam System?

COOLING LOAD CALCULATION SHEET

Project Name : .... Prepare by : .... Revision : ....

Location : .... Approved by : .... Sheet No. : ....

	SPACE USED FOR		Switchgear/CCR Building			
	SIZE WxLxH (M)	40	14	3	LOCATION	
3 & 4	AREA (m2)	560	VOLUME (M3)	1680	MAINDECK	
	ITEM	AREA OR QUANTITY		SUNGAIN OR TEMP. DIFF		FACTOR U VALUE
	SOLAR GAIN-GLASS (Watts)					-
	GLASS	0	m^2 X	341.14	X	0.94
	SKYLIGH	0	m^2 X	341.14	X	0.94
5	SOLAR & TRANS. GAIN-WALLS & ROOF (Watts)					-
	WALL NW	0	m^2 X	19	X	0.34
	WALL SE	0	m^2 X	15	X	0.34
	WALL NE	0	m^2 X	16	X	0.34
	WALL SW	0	m^2 X	17	X	0.34
	ROOF-SUN	0	m^2 X	28	X	0.49
	ROOF-SHADED	0.00	m^2 X	15	X	0.34
	TRANS. GAIN-EXCEPT WALLS & ROOF (Watts)					-
	ALL GLASS	0	m^2 X	12	X	1.07
	PARTITION	0	m^2 X	12	X	0.42
	CEILING	0	m^2 X	12	X	0.42
	FLOOR	0.00	m^2 X	12	X	0.42
6	INFILTRATION	0	L/s X	12	X	1.2
3 & 7	INTERNAL HEAT (Watts)					-
	PEOPLE	0	people X	72	W	0
	EQUIP HEAT	0.00	kW X	1000	W/m2	0
	LIGHT	0.00	m2 X	12.19	W/m2	0
	APPLIANCE ETC.					
	ADDITIONAL HEAT GAIN					
2 & 3	SUB TOTAL 1 (Watts)					-
	STORAGE	0	m2 X	3	X	0.4
	SUB TOTAL 2 (Watts)					-
7	SAFETY FACTOR	0		%		
	ROOM SENSIBLE HEAT (Watts)					186,174
	SUPPLY DUCT HEAT GAIN %	+ 3	SUPPLY DUCT LEAK LOSS %	+ 2	FAN HG	5 %
8	OUTDOOR AIR	1153.0	L/s X	12	oC X 0.06	BF X 1.2
	EFFECTIVE ROOM SENSIBLE HEAT(Watt)					205,788
6	LATENT HEAT (Watt)					360
	INFILTRATION	0	L/s	15	g/kg	
3 & 7	PEOPLE	6	PEOPLE X	60	W	
	STEAM	0	LB/HR X 1050			
	APPLIANCE ETC.		0		X	0
	ADDITIONAL HEAT GAIN		0			
5	VAPOR TRANS.					
7	SAFETY FACTOR	5	%			
	ROOM LATENT HEAT (Watt)					378
	SUPPLY AIR DUCT LEAK LOSS			2	%	
8	OUTDOOR AIR	1153	L/s X	23.9 g/kg X	0.06	BF X 3.0
	EFFECTIVE ROOM LATENT HEAT (Watt)					5,346
	EFFECTIVE ROOM TOTAL HEAT (Watt)					211,134
	OUTDOOR AIR HEAT					93,317
	SENSIBLE :	1153.0	L/s X	12 oC	X (1- 0.06	BF) X 1.2
	LATENT :	1153	L/s X	23.9 g/kg	X (1- 0.06	BF) X 3.0
7	RETURN DUCT HEAT GAIN %	5	RETURN DUCT + LEAK GAIN %			2
	ROOM SENSIBLE HEAT FACTOR			RSHF		1.00
	GRAND TOTAL HEAT FACTOR			GTHF		0.71
	SUB TOTAL 4 (Watt)					100,780
	GRAND TOTAL HEAT (Watt)					311,914

ESTIMATE FOR	15.00 PM	LOCAL TIME SUN TIME	PEAK LOAD	12.00 AM	LOCAL TIME SUN TIME	
HOUR OF OPERATION			24			
CONDITIONS	DB	WB	% RH	DP	g/kg	
OUTDOOR (OA)	35	33.4	90	-	32.6	
ROOM (RM)	23	16.2	50	-	8.7	
DIFFERENCE	12	-	-	-	23.9	

OUTDOOR AIR

VENTI-LATION: 6 PEOPLE X 12 L/s per pax = 72; 560.00 m2 X 0.3 L/s per m2 = 168; L/s VENTILATION = 168

EXFIL-TRATION: ROOM PRESSURIZATION 50 Pa; Ventilation Required =; As per Design Data Input 1210 L/s

OUTDOOR AIR THRU APPARATUS 1153.0 L/s_{OA}

APPARATUS DEWPOINT

ESHF: EFFECTIVE SENS. HEAT = EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT = 0.975

ADP: INDICATED ADP 11.8 oC , SELECTED AD 11.8 oC

DEHUMIDFIED AIR QUANTITY

TEMP. RISE: (1 - 0.06 BF) X (T_{RM} 23 oC - T_{ADP} 11.8 oC) = 10.528 K

DEHUM FLOW: EFFECTIVE ROOM SENS. HEAT / 1.2 X 10.528 $K_{TEMP.RISE}$ = 16,332 L/s_{DA}

OUTLET TEMP.: ROOM SENS. HEAT / 1.2 X 16332 L/s_{DA} = 9.50 $K_{(RM-OUTLET AIR)}$

SUPPLY AIR QUANTITY

SUPPLY AIR FLOW: ROOM SENS. HEAT / 1.2 X 9.50 $k_{DESIRE DIFF}$ = 16,332 L/s_{SA}

BYPASS AIR FLOW: 16332 L/s_{SA} - 16,313 L/s_{DA} = 19 L/s_{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

MIXING AIR: T_{RM} 23 oC + 0.07 OA/SA X (T_{OA} 35 oC - T_{RM} 23 oC) = T_{EDB} 23.8 oC

LEAVING AIR: T_{ADP} 11.8 oC 0.06 BF X (T_{EDB} 24 oC - T_{ADP} 11.8 oC) = T_{LDB} 12.5 oC

FROM PSYCH. CHART : T_{EWB} 18 oC , T_{LWB} 12.2 oC

GRAND TOTAL COOLING LOAD

DIFF. ENTHAL-PY: ENTER AIR ENTHALPY 50.67 kj/kg; LEAVING AIR ENTHALPY 34.67 kj/kg; DIFFERENT ENTHALPY 16 kj/kg

TOTAL COOLING LOAD: 16,332 L/s x 1.2 x 16 = 313582 Watt; MARGIN FACTOR = 10%; COOLING LOAD = 344940 Watt

* IF THIS DIFF TEMP IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMLA.

*WHEN BYPASSING MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIFIED CFM.

Load calculations for each zone

1. Sensible Load
2. Latent Load
3. Ventilation

Air Handler Selection

1. DA Temperature and RH%

Space Condition Occupied and Unoccupied

1. Temperature and RH%

Chilled Water and Hot Water Supply

1. Supply Water Temp

Noise Criteria

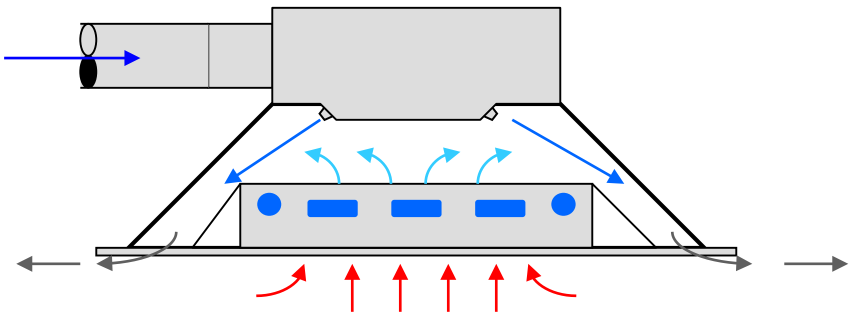
DB or NC

Chilled Beams

Chilled Beam System Design

Total space primary airflow requirement is the greater of:

Pretreated Primary Air

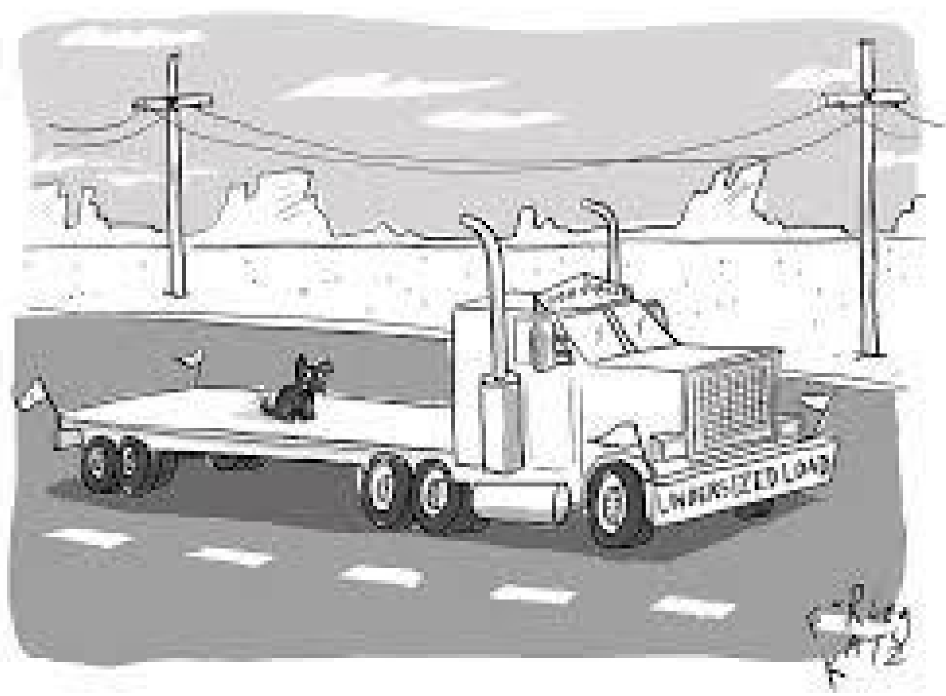


- Volume flow rate needed to accomplish mandated ventilation to space
- Volume flow rate needed to for space heat gains
- Volume flow rate needed to maintain space dew point temperature

Chilled Beams

System Design: Oversize or Undersize Zones

25% Rule



If your coil capacity is less than 25% of the load, why are you doing Chilled Beams?

OR

If your Ventilation and Latent Load is more than 75% of the total load for the space.

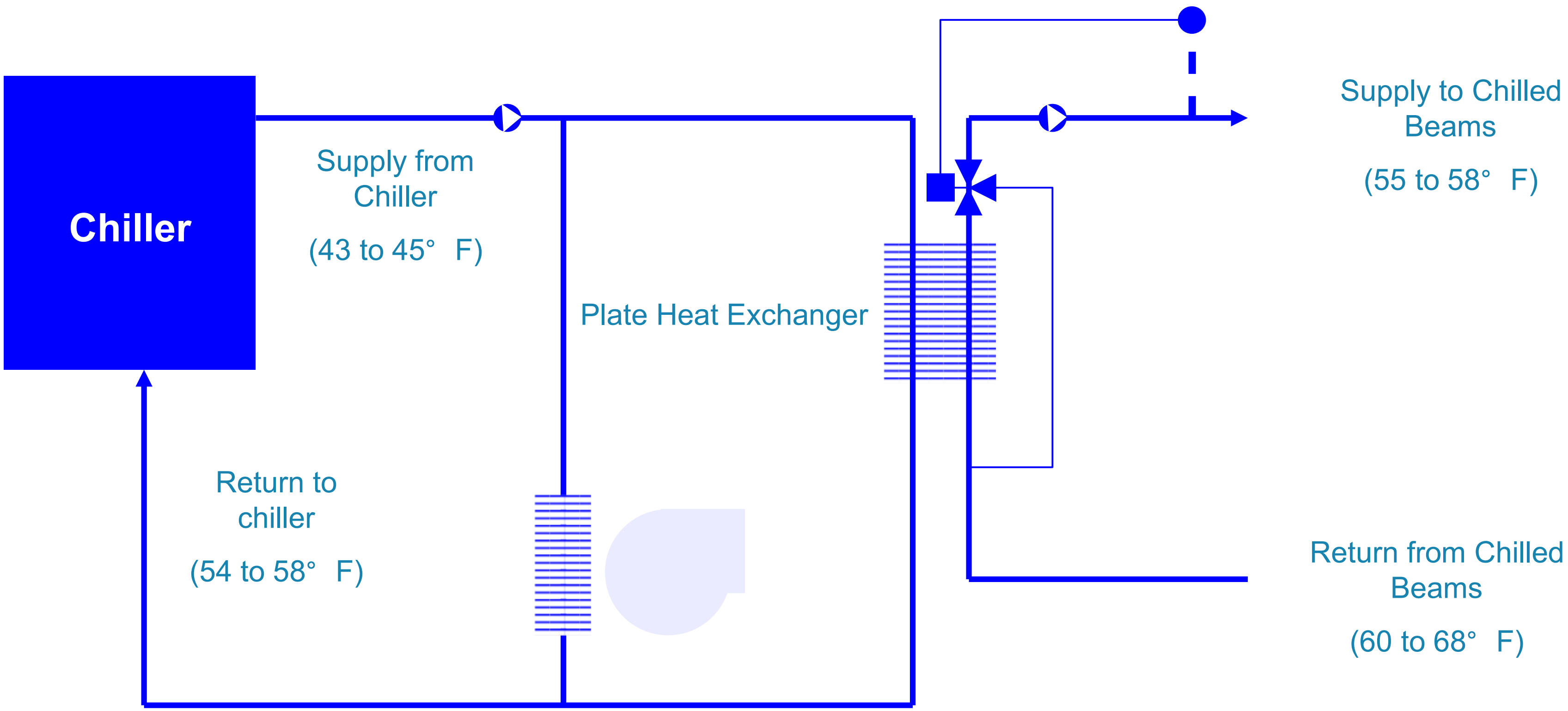
Chilled Beams

Chilled Beam Water System Design & Control

Chilled Beams

Chilled Water Supply

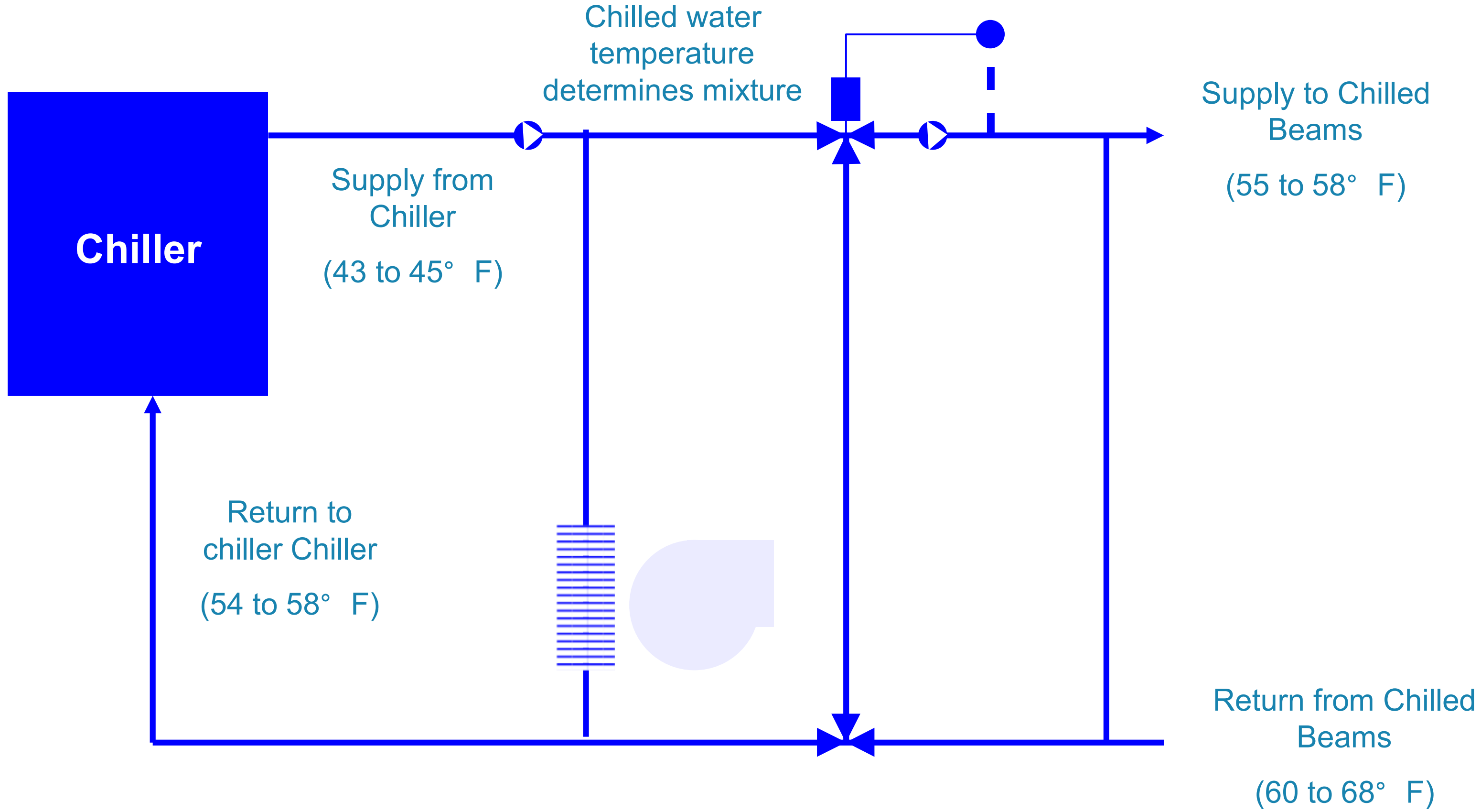
Closed Loop, Shared Chiller Configuration



Chilled Beams

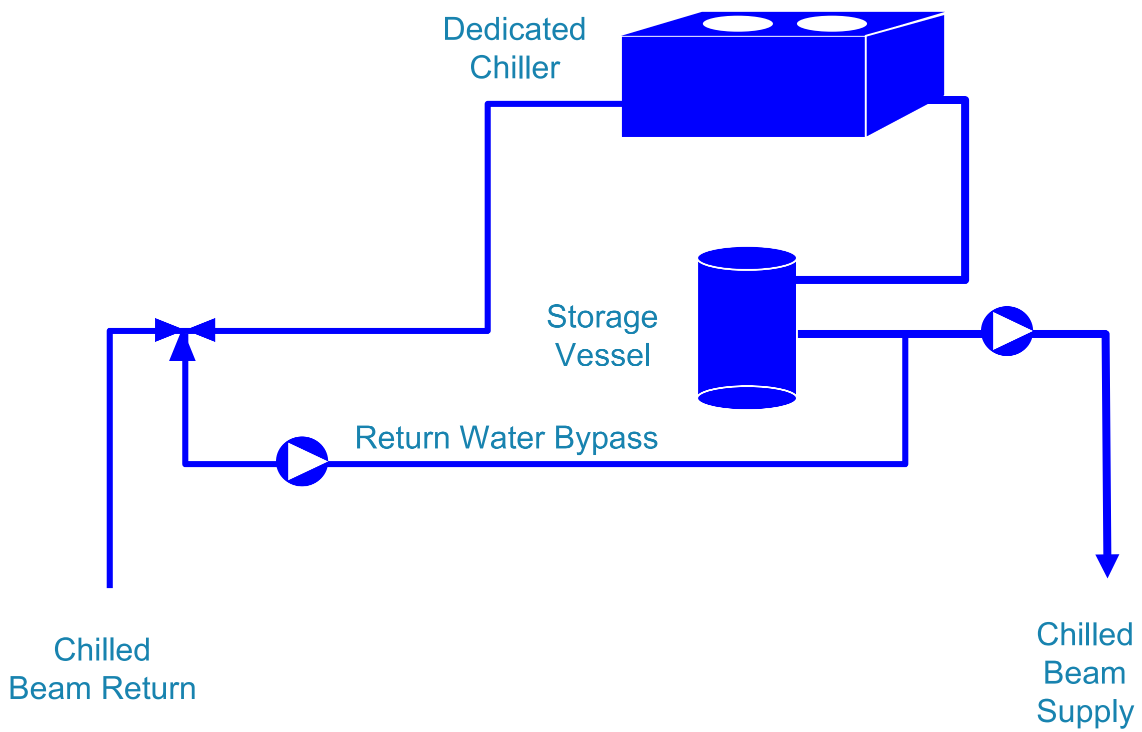
Chilled Water Supply

Open Loop, Shared Chiller Configuration



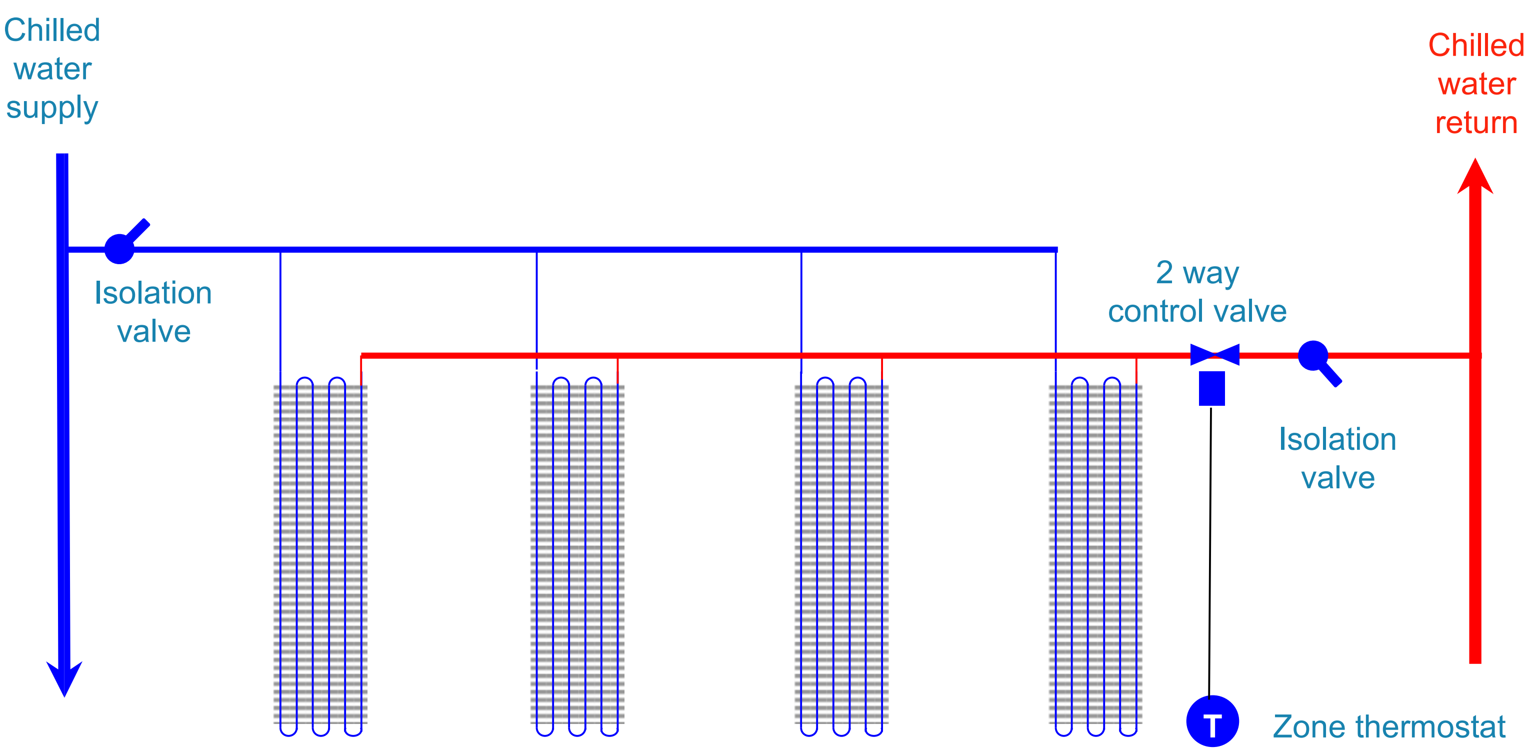
Chilled Beams

Chilled Water Supply



Chilled Beams

TC and Zoning



Multiple chilled beams within a single thermal zone

Piping design best option Reverse Return

19.7- Zone Piping

Chilled Beams

Chilled Beam Selection

Chilled Beams

Sensible Cooling Determinants

The sensible cooling capacity of the chilled beam’s coil is a function of:

- **Primary air supply temperature and flow rate**
  - Air Temperature affects the coil sensible cooling contribution
  - Airflow rate affects the beam’s induction capabilities
- **Chilled water supply temperature and flow rate**
  - Affect chilled beam coil’s sensible cooling capacity
  - Chilled water flow rate limited by water side pressure loss
  - Water supply temperature is limited by the room dew point
- **Nozzle selection**
  - Nozzle velocity determines induction capacity

– Nozzle velocities limited by air pressure drop and noise

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Nozzle Selection/Primary Air Considerations

- Nozzle characteristics
  - Smaller nozzles create largest induction ratios (greater jet surface area), used where primary airflow requirements are high.
  - Larger nozzles enable highest beam primary airflow rates (greater flow cross sectional area), used in spaces with moderate sensible heat gains and ventilation requirements.

- Beam primary airflow rate determination
  - Driven by airside pressure drop and NC level
  - In general, NC should not exceed 30 and air side pressure loss should be ≤ 0.75 in. H_2O

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Beam Selection Suggestions

- Primary airflow rate determination

- Chilled and/or hot water flow rate determination
  - Water velocity through coil should not exceed 4 FPM (ASHRAE Handbook)
  - Water pressure drop should be limited to no more than 10 feet
  - Hot water temperature and flow rate should limit the temperature differential between the supply and room air to 15°F or less (ASHRAE Handbook)

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Basics of Chilled Beams

- Potential for:
  - Reduced Fan Capacity
  - Reduced Cooling Capacity
  - Reduced Ductwork Sizing
  - Reduced Noise
  - Reduced Reheat Potential
  - Reduced Maintenance in the Space
  - Reduce Duct Static at the Fan and in the Space
  - Improved Chiller Efficiencies

Chilled Beams

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Questions?
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This training session is accredited for 1 Professional Development Hour (PDH)

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Questions for the Test

1. What percentage reduction in air handler capacity do you get with a chilled beam system?
2. What is the preferred water piping design in a chilled beam system?
3. What is the range of acceptable static pressure in a chilled beam plenum?
4. How many BTU's in a linear foot of chilled beams?
5. Why do chilled beam systems help give chillers better performance "IPLV"?
6. Who is staring in the our selection software video?