SISTEMAS DE ÁGUA GELADA

PROGRAMA BRASILEIRO DE ELIMINAÇÃO DOS HCFCs

Projeto para o Gerenciamento de Chillers

Projeto Demonstrativo para o Gerenciamento Integrado no Setor de Chillers

The New ASHRAE/REHVA Active and Passive Beam Application Design Guide

Peter Simmonds– Building and Systems Analytics

27/04/2016 – São Paulo

Execução

SOMAR

Implementação

PNUD

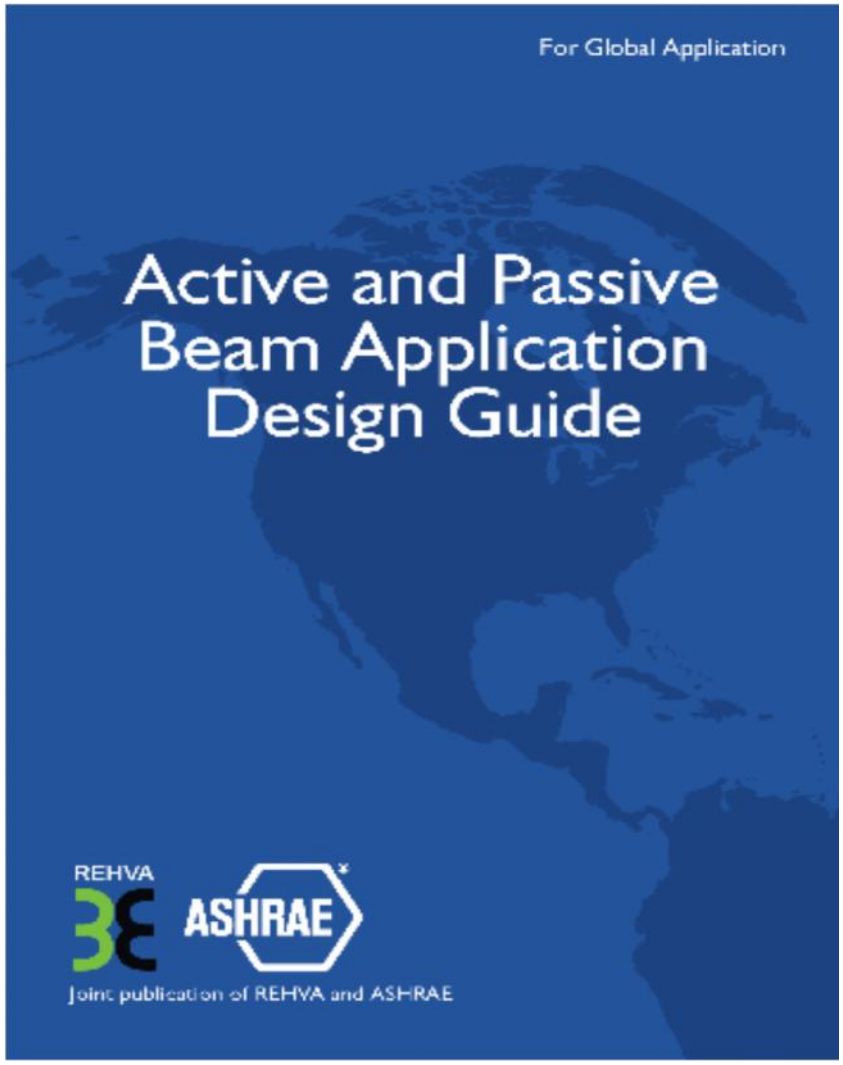
Empoderando vidas. Fortalecendo nações.

Realização

Ministério do Meio Ambiente

GOVERNO FEDERAL BRASIL PÁTRIA EDUCADORA

Active and Passive Beam Application Design Guide is the result of collaboration by worldwide experts to give system designers a current, authoritative guide on successfully applying active and passive beam technology.



Hypothesis

- *Chilled Beams are becoming more and more popular as their efficiency increases and building owner's become comfortable with the technology. With every new technology come new challenges. Active or Passive, chilled beams are here to stay.*

Learning Objective

- *Define the basic design principles of chilled beams*
- *Demonstrate chilled beam installation guidelines*
- *Assess chilled beam operation using functional testing*
- *Examine what not to do through the mistakes of others*

Design Experience

- First designs with passive beams-1983
- "The Utilization and Optimization of A Buildings Thermal Inertia in Minimizing the Overall Energy Use", ASHRAE Transactions 1991 V97 Pt2.
- "The Design, Stimulation and Operation of a Comfortable Indoor Climate for a Standard Office", ASHRAE/DOE/BTEC conference, Clearwater Beach, FL 1992.
- "Thermal Comfort and Optimal Energy Use", ASHRAE Transactions 1993 V99 Pt1.
- "Designing Comfortable Office Climates", ASHRAE, Building Design Technology and Occupant Well-Being in Temperate Climates, Brussels, Belgium, February 1993.
- Dynamic Comfort Control", CIBSE National Conference, Manchester 1993.
- "Control Strategies for a Combined Heating and Cooling Radiant System", CIBSE National Conference, Brighton 1994.

20 years ago

CH-93-10-4

THERMAL COMFORT AND OPTIMAL ENERGY USE

P. Simmonds
Member ASHRAE

Cooling Capacity Comparison

Energy

- On a Mass Flow Rate Basis:-
- 1 lbs of chilled water (6°Δt) transports 4x more cooling energy than 1 lbs of air (20°Δt)

- As water weighs 800 times that of air

- On a Volume Flow Rate Basis:-
- 1 FT^3 of chilled water transports 1000 more cooling energy than 1 FT^3 of air (20°Δt)

Cooling Capacity Comparison

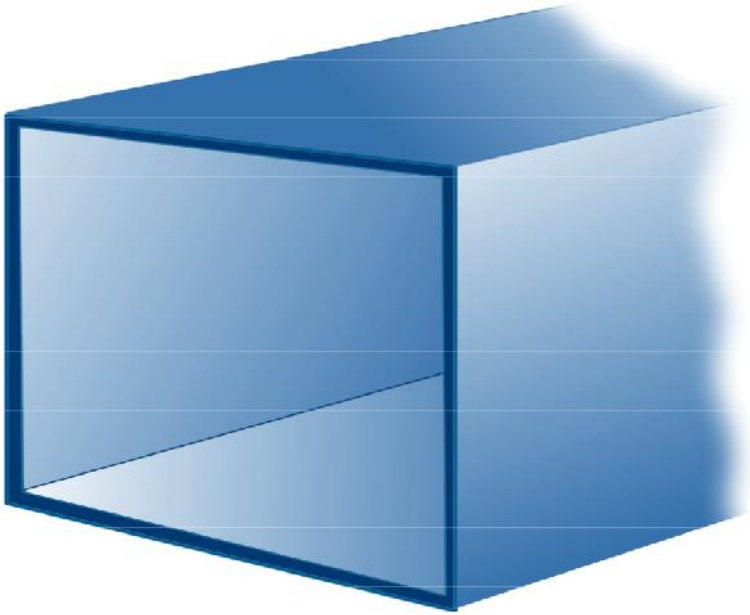
Flow Cross Section Ratio

1 : 327

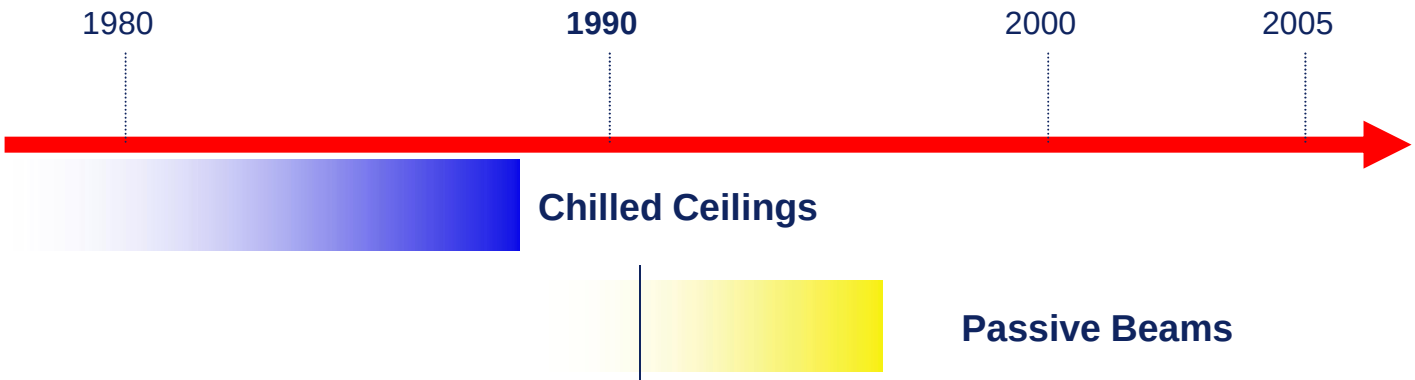
18“ x 18“

Air Duct

1“ diameter
Water Pipe



Passive Chilled Beams

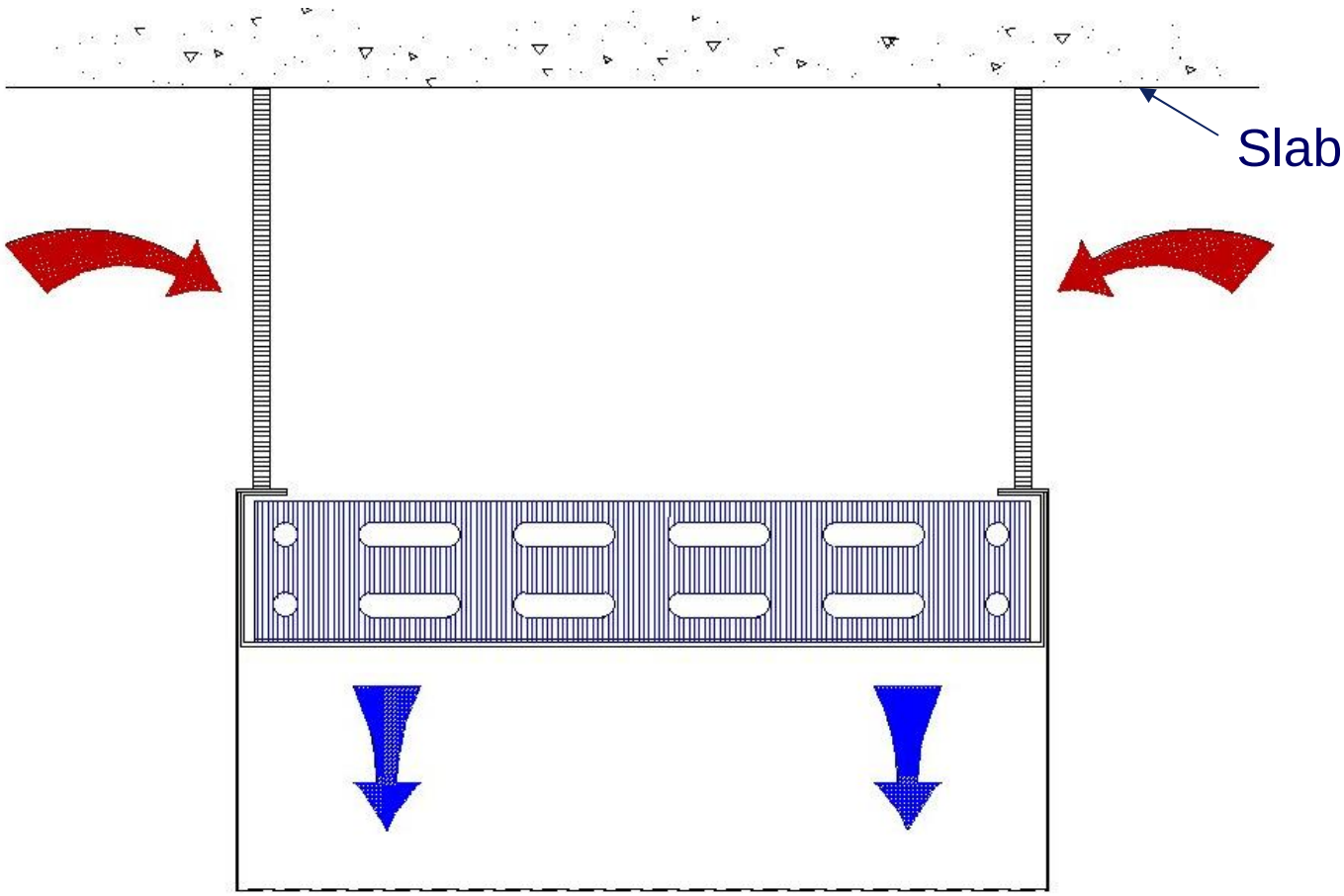


- **Increased equipment loads**
- **Greater occupant densities**
- **Inadequate perimeter cooling**

What is a Passive Chilled Beam?

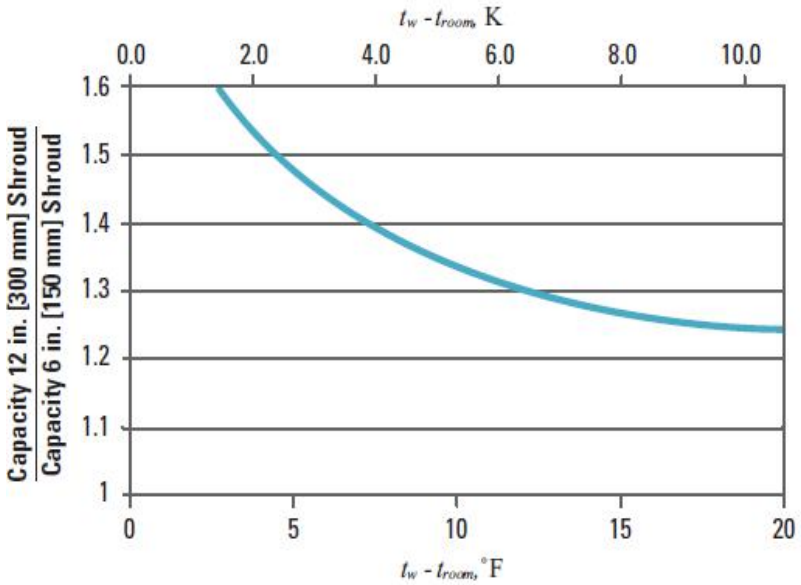
A sensible cooling only device that uses chilled water above the room dew point to remove heat from the space

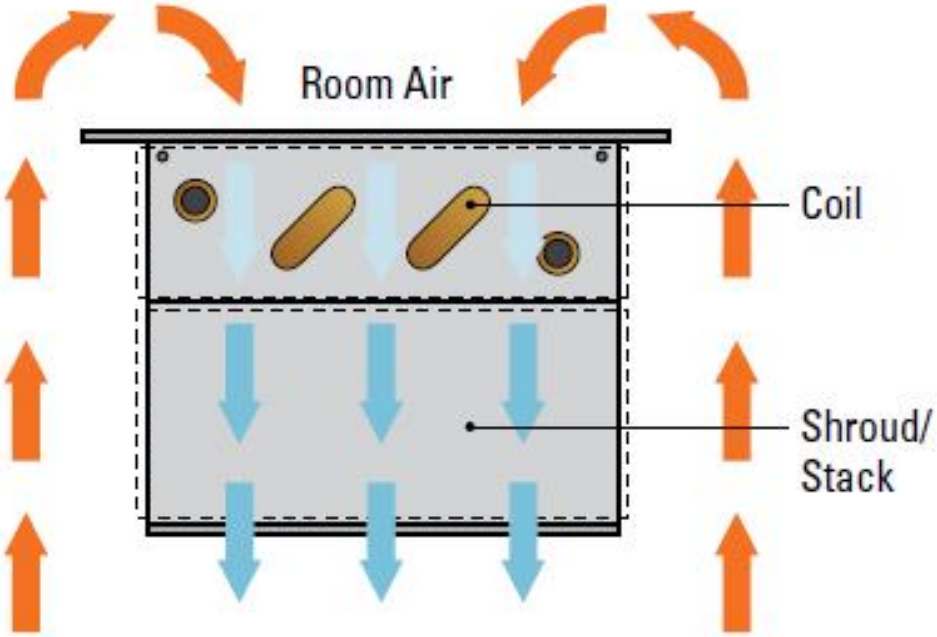
Passive Beam



Passive Beam Concept

- Buoyancy forces promote the circulation of room air through the chilled water coil
- No primary air is supplied to the beam





Passive Beam Concept

Passive chilled beam for recessed installation

Passive chilled beam for exposed installation

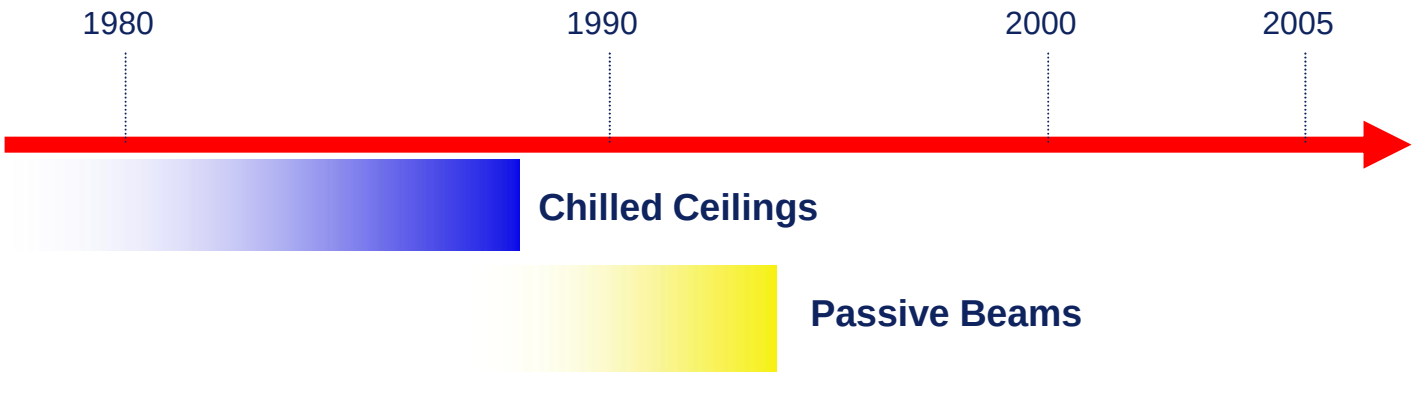
Passive Chilled Beam Benefits

- Improved thermal comfort
- Reduced energy costs
- Higher cooling capacity than ceilings – 50-250 W/m
- Do not require air to work, air usually introduced at low level
- Smaller ducts save space
- Are not affected by relocation of partitions
- Self regulating, simple on/off controls
- Low noise
- Low maintenance
- Excellent for perimeter applications in UFAD systems

Design Considerations

- Sensible cooling only
  - Latent gains must be controlled by air system
- Clearance required between top of coil and underside of slab
- High free area metal perforation ceiling required
  - Low free area ceilings significantly reduce output
  - 28% free area minimum
  - The perforation is *critical* to the performance of the beam
- Can not be used to heat
  - Separate heating system required
- Water side pressure drop 10 kPa

Active Chilled Beams



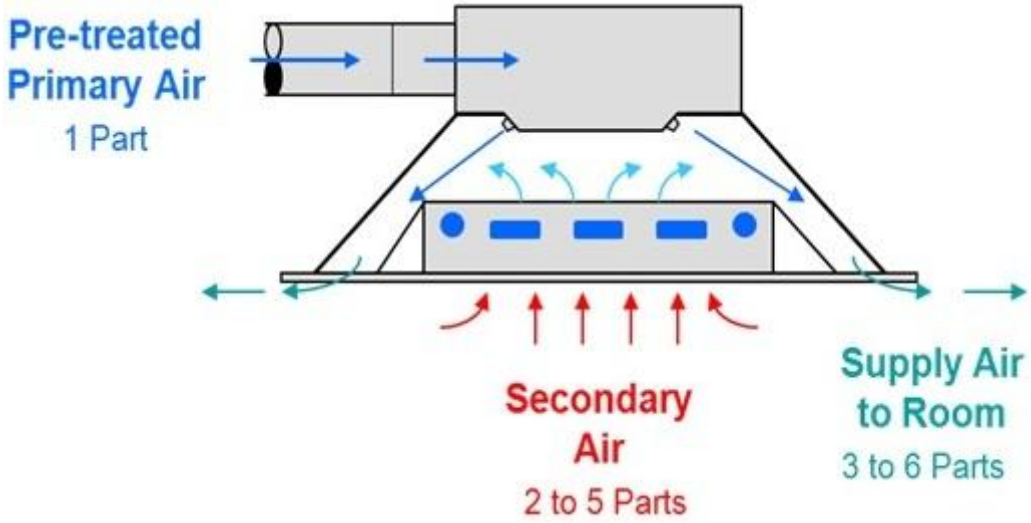
- Continually increasing sensible loads
- Greater occupant densities
- Gypsum board tiles become common
- Combine cooling and ventilation

What is an Active Chilled Beam?

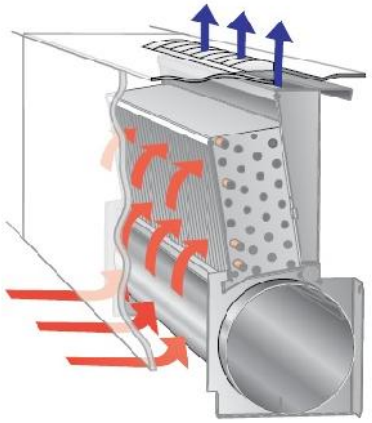
A sensible cooling only device combined with, a method of introducing primary (fresh) air to the space.

Active Beam Concept

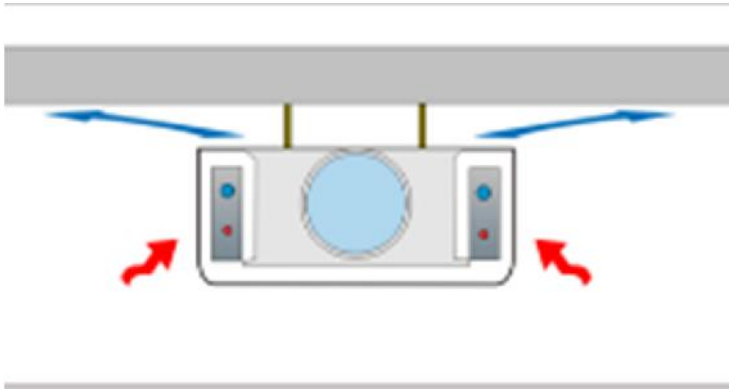
- Primary air is supplied to beam plenum and forced through jet nozzles
- Room air is induced and forced through water coil (cooling or heating)
- Mix of primary and cooled secondary air is supplied through an air diffuser



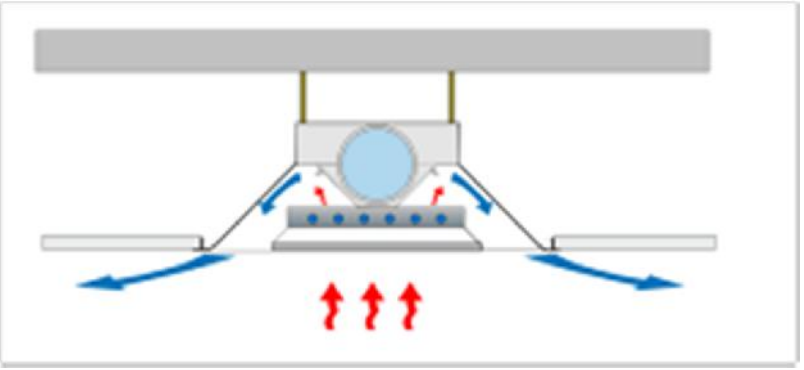
Active Beam Designs



Perimeter wall instalation, under the window sill



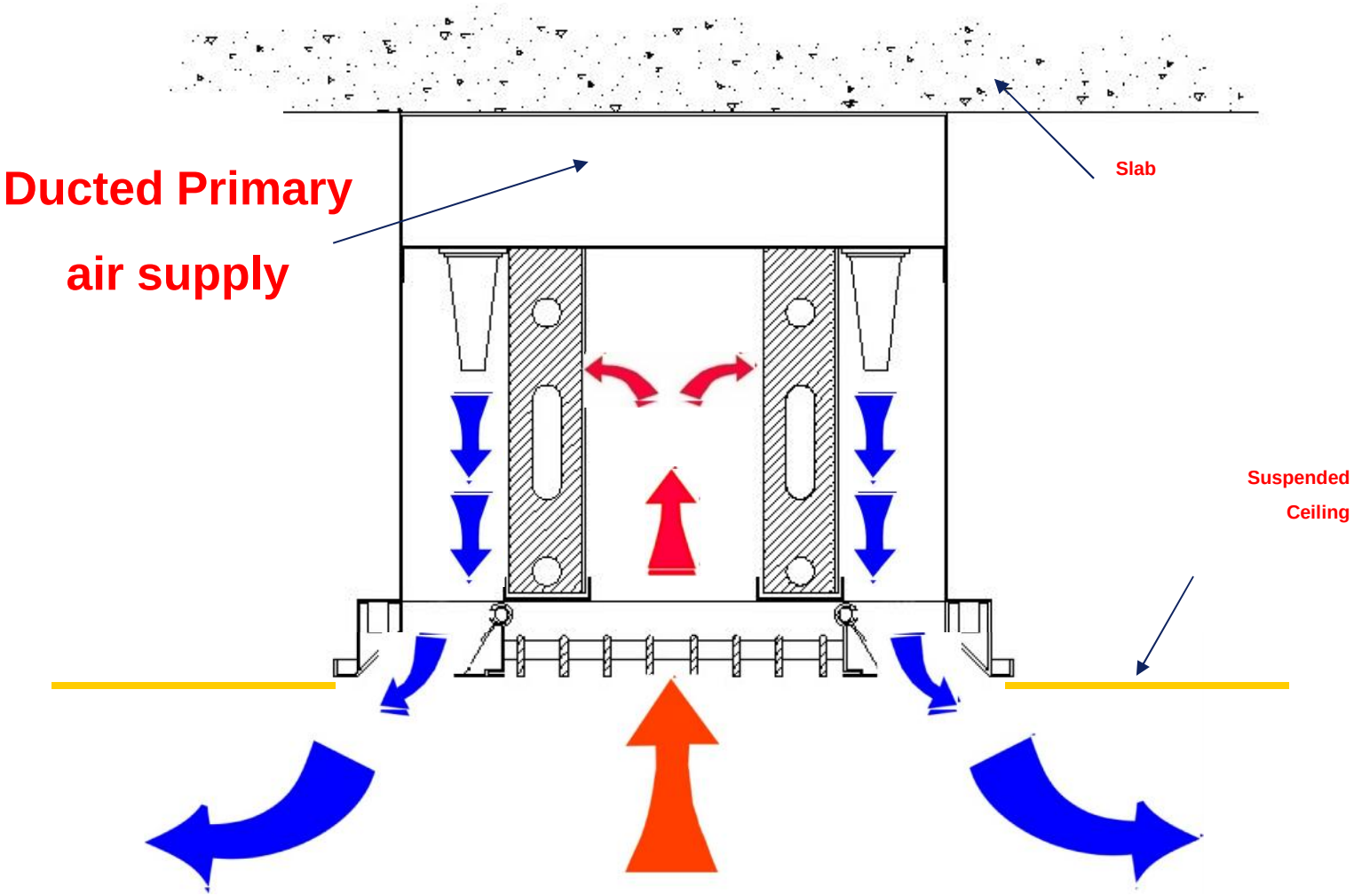
Exposed installation



Recessed installation

- Four way;
- Hotel room;
- Under floor;
- etc.

Active Beam

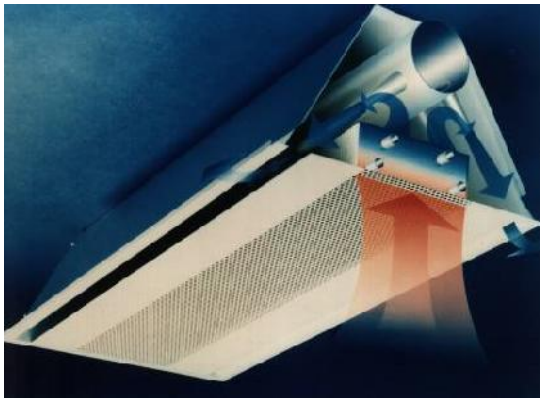


Practical Guidelines

- Active beams can typically handle sensible cooling capacities up to 120W/m^2 of floor area. Management of higher loads (i.e. heat driven laboratories) can be accomplished but may require a more detailed analysis
- Chilled water temperature 14-18°C
- Heating water temperature between 40 and 60°C.
- Inlet static pressure 50 and 250Pa.
- ΔT through the coil 2 – 4K
- Active beams are a good choice for the following applications:
  - Spaces with typical heating and sensible cooling requirements
  - Buildings with moderate internal latent loads
  - Spaces with limited floor to ceiling heights
  - Spaces where low noise levels are desired

Active Beam Benefits

- Higher cooling capacity than passive beams
  - 120 W/m2
- Significantly lower energy costs than VAV
- Integrated cooling and ventilation
- Can be used in all ceiling types
- Controllable discharge pattern
- Heating option
- Self regulating, simple on/off controls
- Low maintenance
- Can be installed directly to slab



Design Considerations

- Sensible cooling only
  - Latent gains controlled by air system
- Air requirements typically 2 x minimum fresh air
- Air side pressure drop typically 100 – 175 Pa
- Water side pressure drop 18 kPa
- Similar layout to VAV with all services in ceiling
- Can be installed directly to slab

Active Beam Design and Selection Process Methodology

- Are beams suitable for space?
  - E.g. High latent / sensible ratio rooms, air driven labs, kitchen areas not suitable
- Consider heating options – dictates orientation of beams
  - Fin tube, chilled beams, duct reheat coils or radiant panels
- Compute and schedule ventilation and latent air and room loads
  - Decouple latent and sensible loads
  - Consider designing to 55% RH – reduces amount of latent air required
  - Schedule higher of the two for min. beam air
- Choose beam orientation in room
  - E.g. Parallel to glazing if heating
- Select beams to maximize water cooling and minimize air delivery
  - Ensure recommended design velocities are achieved, use selection software that computes velocity at wall and collision points.
  - Chilled beams are diffusers as well as cooling/heating devices

Input Water Flow Rate (s)

Input Beam Length and Nozzle Type

Input Primary Airflow Rate

Input Beam Mounting Details for Local Velocity Predictions

Input Primary air, Room and CWS Temperatures

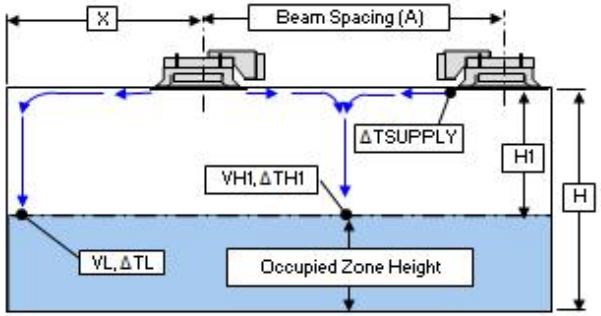
22-HC Two Way Active Chilled B

Input DID	4 pipe coil		2 pipe coil		Comment
	cooling	heating	cooling	heating	
Vwater DID	2.10 GPM	1.50 GPM	0.50 GPM	1.50 GPM	
Unit length	10.0 ft				
Nozzle-type	Z				
y DID	50.0 CFM				
eter	6.0 inches				

eratures	cooling		heating	
Tair-primary (EAT)	55.0 °F		55.0 °F	
Troom / rel. Humidity	75.0 °F	50.0 %	75.0 °F	50.0 %
Twater-flow (EWT)	57.0 °F		125.0 °F	

Input Room Dimensions	
Room Heights (H)	8.0 ft
A	10.0 ft
X	6.0 ft
Occupied Zone Height	6.0 ft

TROX® TECHNIK
The art of handling air



Results	4 pipe coil		2 pipe coil	
	cooling	heating	cooling	heating
Δtwater	-3.08	8.7 °F	-10.12	12.1 °F
Twater-return (LWT)	60.1 °F	116.3 °F	67.1 °F	112.9 °F
ΔT room - water flow	-18.0 °F	50.0 °F	-18.0 °F	50.0 °F
ΔT Room water average	-16.5 °F	45.6 °F	-12.9 °F	43.9 °F
Qwater DID	-3237 BTUH	6538 BTUH	-2532 BTUH	9090 BTUH
Qair DID	-1090 BTUH	-1090 BTUH	-1090 BTUH	-1090 BTUH
Q DID	-4327 BTUH	5448 BTUH	-3622 BTUH	8000 BTUH
ΔP water	9.968 ft WG	4.320 ft WG	0.950 ft WG	5.244 ft WG
ΔP air	0.38 inches WG			
(including 10 dB room absorbtion)	15			

Output: Sensible from Water, Air and Total

Output Waterside, Airside Pressure drop and noise

NOTE: This calculation program is only applicable to DID622-HC beams manufactured by TROX USA.

Terminal Velocities and Temperatures					Support Values	
vL2 (measured 2" from wall)	82 FPM	59 FPM	80 FPM	55 FPM		
vL6 (measrured 6" from wall)	49 FPM	36 FPM	48 FPM	33 FPM	N-nozzles total	230
vH1	47 FPM		47 FPM		Aeff	0.022477 ft²
ΔTL	-1.3 °F	0.9 °F	-1.1 °F	1.4 °F	veff	2224.5 FPM
ΔTH1	-0.4 °F		-0.3 °F		H1	2.0 ft
ΔTsupply	-12.4 °F	15.6 °F	-10.4 °F	22.9 °F	L	8.0 ft
Connection-diameter / primary air	6.0 inches				room air dew point-cooling	55.1 °F

Output: Sensible from Water, Air & Total

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4305 Settingdown Circle
Cumming, GA 30028
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Fax: (770) 569-1435
www.TROXUSA.com

Version 3.0
1/1/2009

Text in red represents a value that is not generally recommended (see user notes for details).

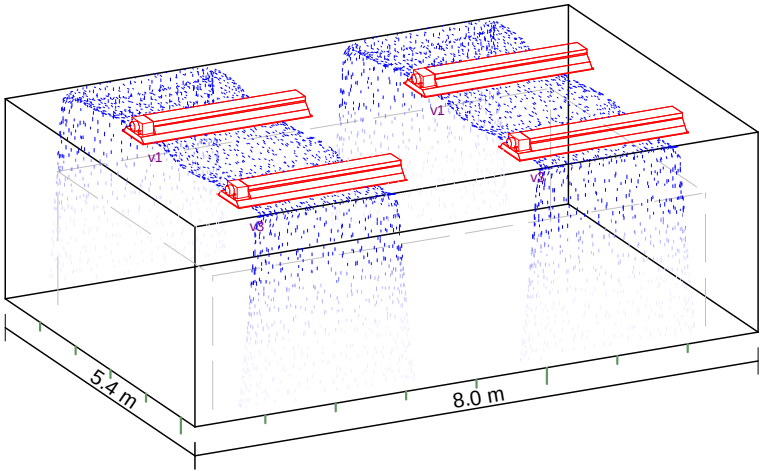
Simulation with CCC chilled beams in 3D

Cooling	CBC/A-125-2400-1800		2005.10
Room:		Supply air flow rate:	180 m³/h (4 x 45 m³/h)
Room size:	8.0 x 5.4 x 2.7 m		25.0 m³/(hm), 4.2 m³/(hm²)
Occupied zone:	h=1.8 m / dw=0.5 m	Supply air temperature:	14.0 °C
Room air:	24.0 °C / 50 %	Primary air capacity:	597 W (4 x 149 W)
Heat gain:	2808 W	Total pressure drop:	121 Pa
Installation height:	2.70 m	Total cooling capacity:	2811 W (4 x 703 W)
Inlet water temperature:	14.0 °C		390 W/m, 65 W/m²
Outlet water temperature:	16.5 °C	Dew point temperature:	12.9 °C
Water flow rate:	0.211 kg/s (4 x 0.053 kg/s)	Velocity control:	side=3, middle=2
Coil capacity:	2214 W (4 x 553 W)	L_d:	-
	307 W/m		
Water pressure drop:	2.0 kPa		

vmax in occupied zone:	v1	v3		
v	~0.05 m/s	~0.20 m/s		
v(dt=0)	~0.05 m/s	~0.15 m/s		
▲T	-0.2 °C	-0.9 °C		

Heat sources and their location may influence the velocity and direction of the jet

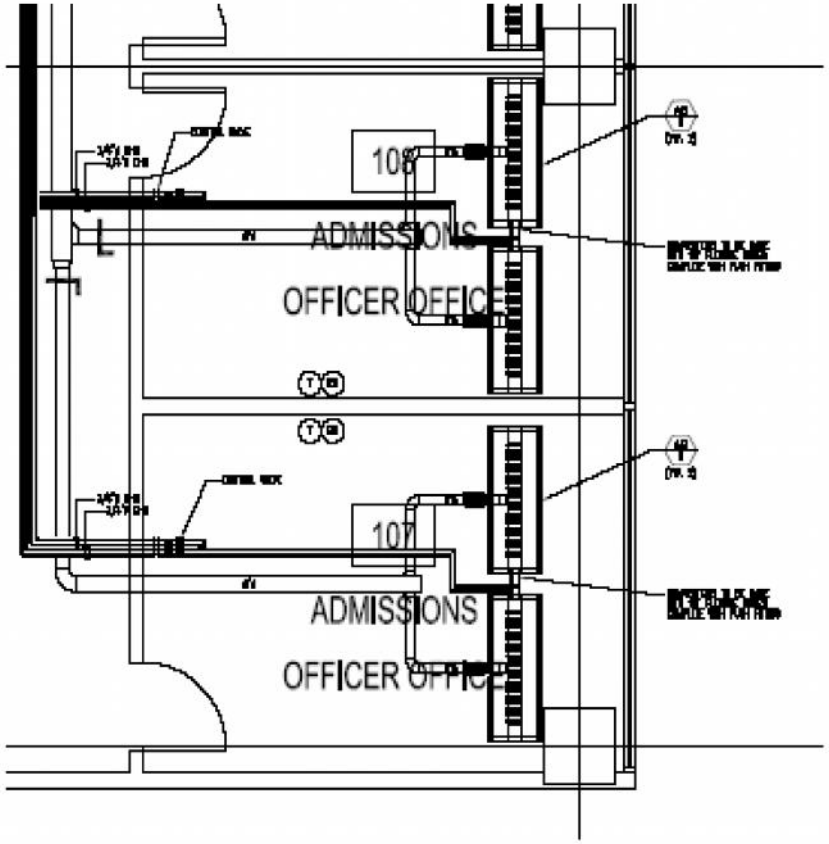
vlim = 0.20 m/s



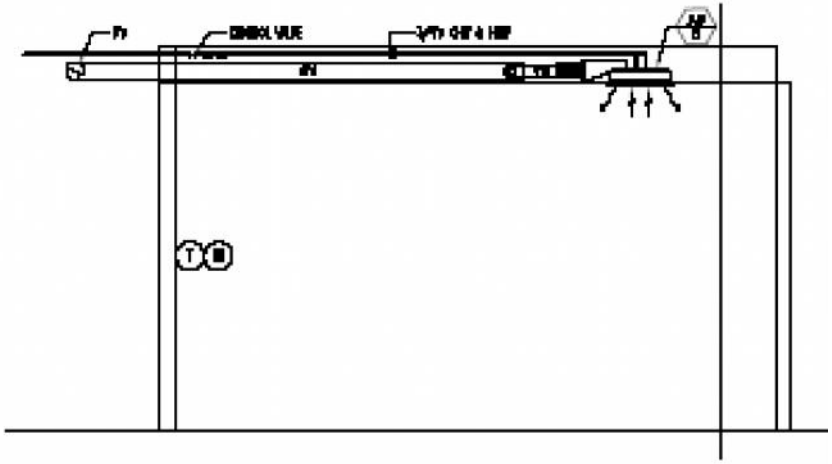
Analysis

- What to look for
- What to do
- What not to do

Typical Office



1 TYPICAL OFFICE ENGLARGED PLAN

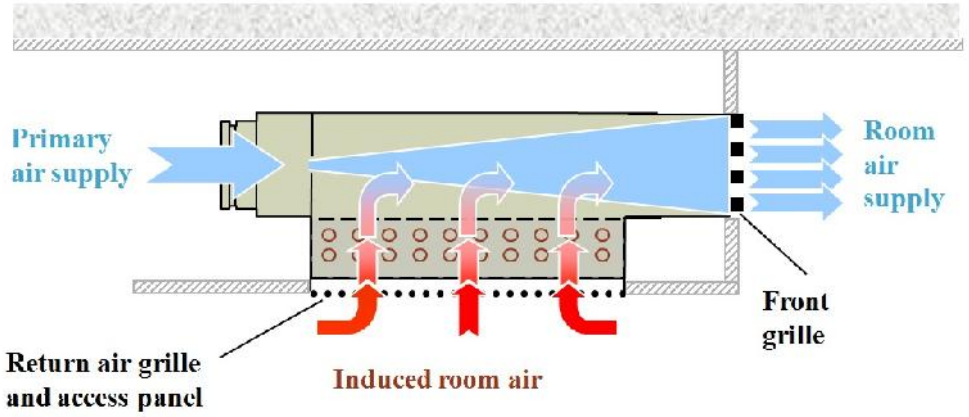


4 TYPICAL OFFICE SECTION

Typical Office

Beam System Applications

Beam System Applications



Murphy's Law of HVAC Engineering

- A load is a load

Primary Air Calculation & Beam Specification

Primary air flow needed for ventilation; Calculation according to EN15251 – category2

description	symbol	value	units	formula/source
floor area	A	16,5	m2	
ceiling height	h	2,8	m	
volume	Vol	46	m3	A x h
occupancy	NP	1	-	
ventilation per person	Rp	7,0	l / s.p	EN 15251 - category 2
ventilation unit area	Ra	0,70	l / s.m2	EN 15251 - category 2 ; low polluting
ventilation requirement	**V1**	**19**	**l/s**	EN15251 : 2007 (Rp x NP + Ra x A)
Air Changes per Hour	ACH	1,4	/h	V1 x 3,6 / Vol

Calculation according to ASHRAE 62.1

description	symbol	value	units	formula/source
occupancy	NP	1	-	
ventilation per person	Rp	2,4	l / s.p	ANSI/ASHRAE 62.1
ventilation unit area	Ra	0,30	l / s.m2	ANSI/ASHRAE 62.1
ventilation requirement	**V1**	**7,4**	**l/s**	ANSI/ASHRAE 62.1 ; (Rp x NP + Ra x A)
Air Changes per Hour	ACH	0,6	/h	V1 x 3,6 / Vol

Primary Air Calculation & Beam Specification

Primary air flow needed for ventilation; Calculation according to EN15251 – category2

Very different requirements from different standards

description	symbol	value	units	formula
floor area	A	16,5	m2	
ceiling height	h	2,8	m	
volume	Vol	46	m3	A x h
occupancy	NP	1	-	
ventilation per person	Rp	7,0	l / s.p	EN 15251 - category 2
ventilation unit area	Ra	0,70	l / s.m2	EN 15251 - category 2 ; low polluting
ventilation requirement	**V1**	**19**	**l/s**	**EN15251 : 2007 (Rp x NP + Ra x A)**
Air Changes per Hour	ACH	1,4	/h	V1 x 3,6 / Vol

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ventilation requirement	**V1**	**7,4**	**l/s**	**ANSI/ASHRAE 62.1 ; (Rp x NP + Ra x A)**
Air Changes per Hour	ACH	0,6	/h	V1 x 3,6 / Vol

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

Choice of the design indoor air dew point temperature, DP_{IDA};

The bigger the DP_{IDA} the smaller the needed air flow for dehumidification.

In this example we choose, DP_{IDA} = 16ºC

description	symbol	value	units	formula/source
IDA design condition cooling	DB_{IDA}	25,0	ºC	Owner Projet Requirements
IDA design condition cooling	DP_{IDA}	16,0	ºC	CWTin - dT
IDA design condition cooling	HR_{IDA}	11,4	g/kg	psychart
IDA design condition cooling	RH_{IDA}	57,5	%	psychart

Primary Air **Calculation & Beam Specification**

Primary air flow needed for dehumidification;

Choice of the design primary air dew point temperature, DP_{SUP};

The choice of the primary air dew point greatly affects the size of the needed air flow for dehumidification and also the technological solution of the primary air handling unit (AHU).

In this example we choose, DP_{SUP} = 13ºC.

Since we choose a primary air dry bulb temperature of 14ºC, the primary air supply dew point temperature can be obtained using a simple conventional AHU configuration without significant energy use for reheat in the dehumidifying process.

Primary Air Calculation & Beam Specification

All the calculations can be organized in a spreadsheet and performed in a very productive way.

The first two parts regard the outdoor air, ODA, and indoor air, IDA, design conditions.

	num	description	symbol	cellS	units	formula/source
ODA design dondition	1	location	-	**Lisbon**	-	
	2	ODA design condition cooling	DB_{ODA1}	**32,1**	ºC	**ASHRAE Fundamentals 1% criteria**
	3	ODA design condition cooling	$MCWB_{ODA1}$	**19,7**	ºC	**ASHRAE Fundamentals 1% criteria**
	4	ODA design condition cooling	HR_{ODA1}	**9,3**	g/kg	**ASHRAE Fundamentals 1% criteria**
	5	ODA design condition dehumid	DP_{ODA2}	**20,0**	ºC	**ASHRAE Fundamentals 1% criteria**
	6	ODA design condition dehumid	$MCDB_{ODA2}$	**22,7**	ºC	**ASHRAE Fundamentals 1% criteria**
	7	ODA design condition dehumid	HR_{ODA2}	14,8	g/kg	**ASHRAE Fundamentals 1% criteria**
	8	ODA design condition heating	DB_{ODA3}	**5,8**	ºC	**ASHRAE Fundamentals 1% criteria**
IDA design conditions	9	IDA design condition cooling	DB_{IDA}	**25,0**	ºC	**Owner Projet Requirements**
	10	IDA design condition cooling	DP_{IDA}	16,0	ºC	CWTin - dT
	11	IDA design condition cooling	HR_{IDA}	11,4	g/kg	psychart
	12	IDA design condition cooling	RH_{IDA}	57,5	%	psychart

Note. In this spreadsheet the values in red + bold are required inputs, the values in black + normal are automatically calculated based on the input values.

Condensation prevention

The occurrence of condensation on the beams is avoided by:

- The supply of an adequate amount of correctly conditioned primary air;
- The implementation of an adequate chilled water temperature control system;
- At morning startup, first turn on the AHU and run the beam CW pump only when the indoor air dew point is below the CWT setpoint.

However, condensation prevention systems are normally applied as a safety measure.

Condensation prevention

Safety condensation prevention can consist on:

- Reactive strategies,

installing condensate detectors that;

  - stop water supply to the beams;
  - Increase CWT setpoint;

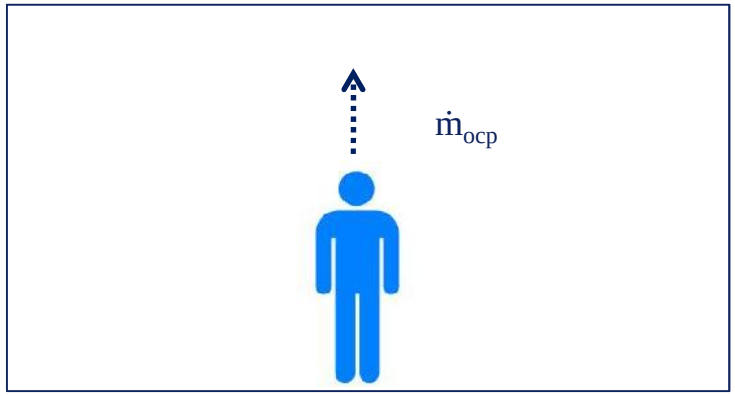
- Proactive strategies ;

  - Window switches stopping CW flow;
  - Monitoring indoor air DP and resetting CWT setpoint above the measured indoor air DP;

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The main water vapour addition to the indoor air is generated by the occupant´s metabolism.



Primary Air Calculation & Beam Specification

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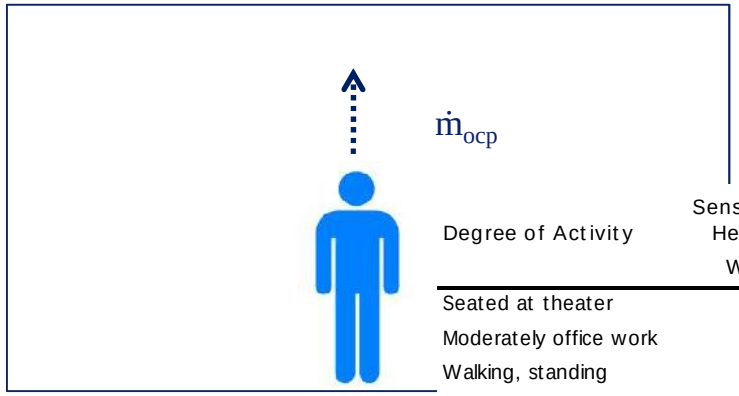
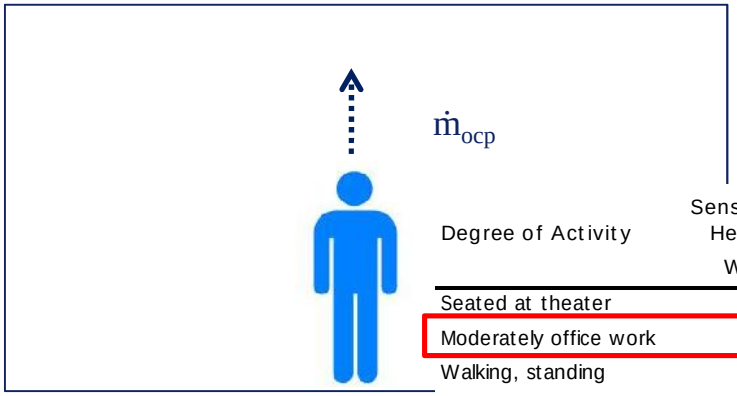


Degree of Activity	Sensible Heat	Latent Heat	water vapour generation	
	W	W	g/s	g/h
Seated at theater	70	35	0,014	50
Moderately office work	75	55	0,022	79
Walking, standing	75	70	0,028	101
Light bench work	80	140	0,056	202
Moderate dancing	90	160	0,064	230
light machine work	110	185	0,074	266
Heavy work	170	255	0,102	367
Athletics	210	315	0,126	454
ASHRAE Handbook of Fundamentals			Calculated	

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The main water vapour addition to the indoor air is generated by the occupant´s metabolism.



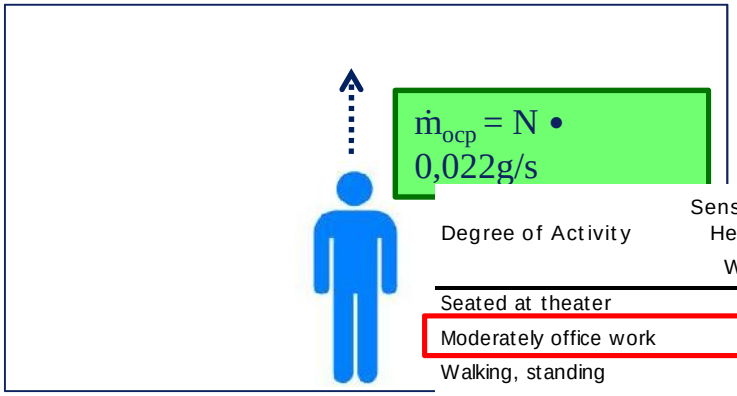
Degree of Activity	Sensible Heat	Latent Heat	water vapour generation	
	W	W	g/s	g/h
Seated at theater	70	35	0,014	50
Moderately office work	75	55	0,022	79
Walking, standing	75	70	0,028	101
Light bench work	80	140	0,056	202
Moderate dancing	90	160	0,064	230
light machine work	110	185	0,074	266
Heavy work	170	255	0,102	367
Athletics	210	315	0,126	454

ASHRAE Handbook of Fundamentals — Calculated

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The main water vapour addition to the indoor air is generated by the occupant´s metabolism.



$\dot{m}_{ocp} = N \bullet 0{,}022 g/s$

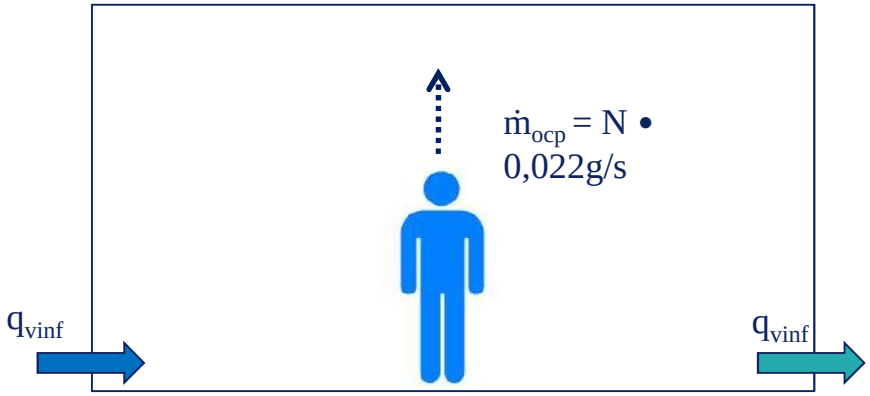
N – number of people

Degree of Activity	Sensible Heat	Latent Heat	water vapour generation	
	W	W	g/s	g/h
Seated at theater	70	35	0,014	50
Moderately office work	75	55	0,022	79
Walking, standing	75	70	0,028	101
Light bench work	80	140	0,056	202
Moderate dancing	90	160	0,064	230
light machine work	110	185	0,074	266
Heavy work	170	255	0,102	367
Athletics	210	315	0,126	454
ASHRAE Handbook of Fundamentals			Calculated	

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The second water vapour addition to the indoor air results from infiltration of outdoor air through the building envelope.



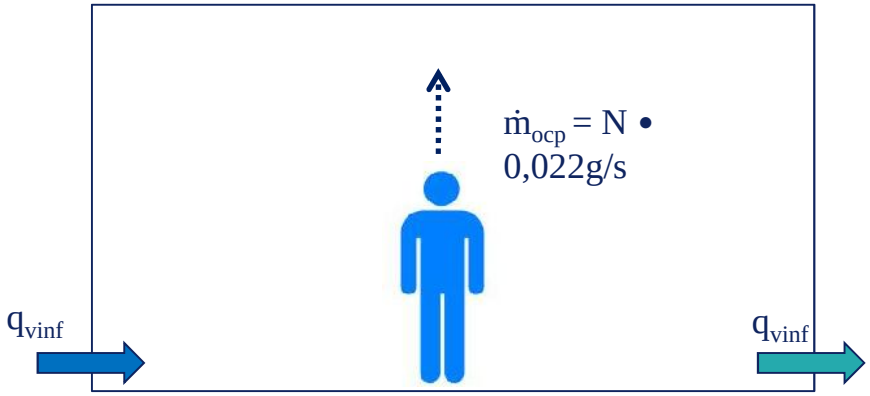
Whenever indoor pressure is lower than outdoor pressure, outdoor air will enter the room through the envelope

Infiltration air entering the building shall leave the building, through the envelope or through the HVAC system, at the indoor humidity ratio

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The second water vapour addition to the indoor air results from <u>infiltrations of outdoor air</u> through the building envelope.



$$\dot{m}_{inf} = q_{vinf} \bullet \rho \bullet (HR_{ODA} - HR_{IDA})$$

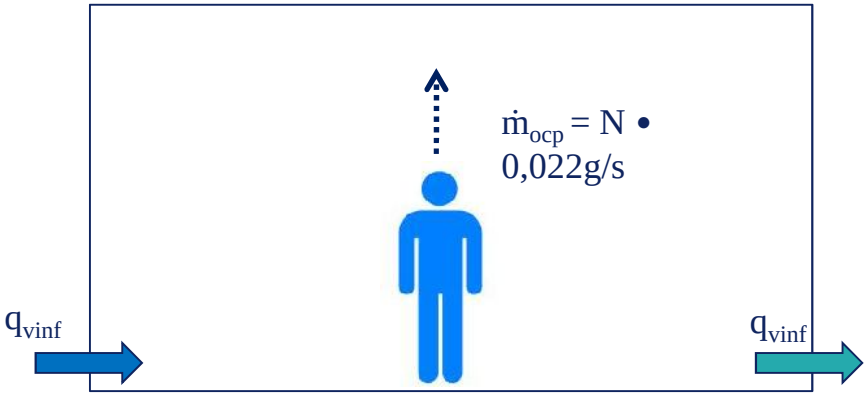
q_{vinf}	(m^3/s)	infiltration air flow
ρ	(Kg/m^3)	air density (1,2)

HR_{ODA}	(g/Kg)	outdoor air humidity ratio
HR_{IDA}	(g/Kg)	indoor air humidity ratio

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

The total water vapour addition to the indoor air is the sum of both sources;



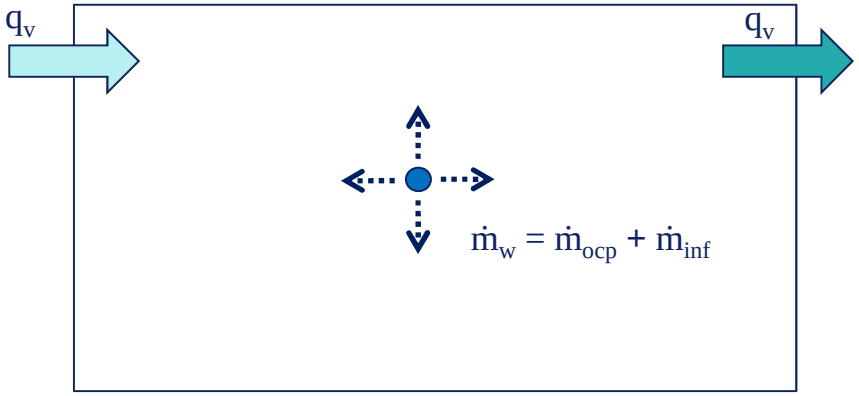
$$\dot{m}_{inf} = q_{vinf} \bullet \rho \bullet (HR_{ODA} - HR_{IDA})$$

$$\boxed{\dot{m}_w = \dot{m}_{ocp} + \dot{m}_{inf}}$$

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

Knowing the strength of the sources, the required indoor air humidity ratio and the primary air humidity ratio the primary air flow needed for dehumidification can be determined.



Mass balance equation applied to the room control volume;

$$q_v \bullet \rho \bullet HR_{IDA} = \dot{m}_w + q_v \bullet \rho \bullet HR_{SUP} \rightarrow q_v = \dot{m}_w \ / \ [\ \rho \bullet (HR_{IDA} - HR_{SUP})\ ]$$

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

Since the dynamic load calculation software delivers the value of the design latent load of the space (L_{LAT}) the strength of the water vapor sources can easily be approximated by using the following formula;

$$\dot{m}_w = 1.000 \bullet L_{LAT} / 2.500 \longrightarrow \dot{m}_w = L_{LAT} / 2{,}5$$

$\dot{m}_w$	(g/s)	;	mass flow of water vapour added to the space
L_{LAT}	(W)	;	latent space load (from load calculation)
1.000	-	;	conversion factor from Kg to g
2.500	(KJ/Kg)	;	approximate heat content of 50% rh vapour at 24ºC less the heat content of water at 10ºC. *Note. A common design condition for the space is 50% rh at 24°C, and 10°C is normal condensate temperature from cooling and dehumidifying coils.*

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

First step, choose the design indoor air and primary air humidity ratio;

Second step, calculate the strength of the water vapor sources;

$$\dot{m}_w = \dot{m}_{ocp} + \dot{m}_{inf}$$

Third step, calculate the needed primary air flow for dehumidification;

$$q_v = \dot{m}_w \ / \ [\ \rho \bullet (HR_{IDA} - HR_{SUP})\ ]$$

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

Choice of the design indoor air dew point temperature, DP_{IDA};

DP_{IDA} must be such that indoor air relative humidity falls inside the comfort range specified in the OPR; $30\% < RH_{IDA} < 60\%$.

	Dry bulb	RH	DewPoint
High limit	25ºC	60%	16,7ºC
Low limit	25ºC	30%	6,2ºC

$$6{,}2^{o}C < DP_{IDA} < 16{,}7^{o}C$$

Primary Air Calculation & Beam Specification

Primary air flow needed for dehumidification;

Choice of the design indoor air dew point temperature, DP_{IDA};

In order to prevent condensation, DP_{IDA} must be equal to or smaller than the chilled water temperature supplied to the beams, CWT_{IN}.

$$DP_{IDA} = CWT_{IN} - dT$$

dT; safety temperature difference

The safety temperature difference, dT, is typically between 0ºC and 1ºC. It's value has a big influence on the dimensioning of the primary air flow and should be kept as small as possible.

Primary Air Calculation & Beam Specification

The third and fourth parts regard the room dimensions and the calculation of the primary air flow required for ventilation.

	num	description	symbol	cellS	units	formula/source
dimensions	13	floor area	A	16,5	m2	
	14	ceiling height	h	2,8	m	
	15	volume	Vol	46	m3	A x h
ventilation	16	occupancy	NP	1	-	
	17	**ventilation requirement**	**V1**	**19**	**l/s**	**EN15251 : 2007 (Rp x NP + Ra x A)**
	18	Air Changes per Hour	ACH	1,4	/h	V x 3,6 / Vol
	19	ventilation per person	Rp	7,0	l / s.p	**EN 15251 - category 2**
	20	ventilation unit area	Ra	0,70	l / s.m2	**EN 15251 - category 2 ; low polluting**

Primary Air Calculation & Beam Specification

The final parts regard the calculation of the air flow needed for dehumidification and the beam selection data.

	num	description	symbol	cellS	units	formula/source
occupancy load	21	occupant load, sens/p	OCP_S	75	W	ASHRAE Fundamentals
	22	occupant load, lat/p	OCP_L	55	W	ASHRAE Fundamentals
infiltration	23	infiltration airflow	INF	3,9	l/s	ACH_{INF} x Vol / 3,6
	24	infiltration air Changes per Hour	ACH_{INF}	0,3	/h	
loads	25	sensible load (clg design cdts)	L_{SENS}	800	W	from loads calcuation
	26	latent load (dehumd.dsg cdts)	L_{LAT}	94	W	NP x OCP_L + (INF/1000) x 1,2 x 2.500 x (HR_{ODA2} - HR_{IDA})
	27	**airflow for dehumidification**	**V2**	**15**	**l/s**	1000 x L_{LAT} / [1,2 x 2500 x (HR_{IDA} - HR_{SUP})]
Beam selection data	28	Beam chilled water temp. in	CWTin	16,0	ºC	
	29	Safety temperature difference	dT	0,0	ºC	CWTin - DP_{IDA}
	30	**primary airflow**	**V**	**19**	**l/s**	max (V1 ; V2)
	31	primary air temperature	DB_{SUP}	14,0	ºC	
	32	primary air dew point	DP_{SUP}	13,0	ºC	psychart
	33	primary air relative humidity	RH_{SUP}	94	%	psychart
	34	primary air humidity ratio	HR_{SUP}	9,4	g/kg	psychart
	35	cooling by air (primary airflow)	Cair	245	W	V x 1,2 x (DB_{IDA} - DB_{SUP})
	36	cooling by water (water coil)	C_W	555	W	L_{SENS} - Cair
	37	cooling by water (water coil)	C_W	69%	%	C_W / L_{SENS}

Primary Air Calculation & Beam Specification

	nun	description	symbol	cellS	cellSE	openplanN	openplanNE	meetingE	interior1	units	formula/source
ODA design dondition	1	location	-	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon	-	
	2	ODA design condition cooling	DB_{ODA1}	32,1	32,1	32,1	32,1	32,1	32,1	°C	ASHRAE Fundamentals 1% criteria
	3	ODA design condition cooling	$MCWB_{ODA1}$	19,7	19,7	19,7	19,7	19,7	19,7	°C	ASHRAE Fundamentals 1% criteria
	4	ODA design condition cooling	HR_{ODA1}	9,3	9,3	9,3	9,3	9,3	9,3	g/kg	ASHRAE Fundamentals 1% criteria
	5	ODA design condition dehumid	DP_{ODA2}	20,0	20,0	20,0	20,0	20,0	20,0	°C	ASHRAE Fundamentals 1% criteria
	6	ODA design condition dehumid	$MCDB_{ODA2}$	22,7	22,7	22,7	22,7	22,7	22,7	°C	ASHRAE Fundamentals 1% criteria
	7	ODA design condition dehumid	HR_{ODA2}	14,8	14,8	14,8	14,8	14,8	14,8	g/kg	ASHRAE Fundamentals 1% criteria
	8	ODA design condition heating	DB_{ODA3}	5,8	5,8	5,8	5,8	5,8	5,8	°C	ASHRAE Fundamentals 1% criteria
IDA design conditions	9	IDA design condition cooling	DB_{IDA}	25,0	25,0	25,0	25,0	25,0	25,0	°C	Owner Projet Requirements
	10	IDA design condition cooling	DP_{IDA}	16,0	16,0	16,0	16,0	16,0	16,0	°C	CWTin - dT
	11	IDA design condition cooling	HR_{IDA}	11,4	11,4	11,4	11,4	11,4	11,4	g/kg	psychart
	12	IDA design condition cooling	RH_{IDA}	57,5	57,5	57,5	57,5	57,5	57,5	%	psychart
dimensions	13	floor area	A	16,5	23,5	23,5	23,5	39,5	31,0	m2	
	14	ceiling height	h	2,8	2,8	2,8	2,8	2,8	2,8	m	
	15	volume	Vol	46	66	66	66	111	87	m3	A x h
ventilation	16	occupancy	NP	1	2	4	4	10	4	-	
	17	**ventilation requirement**	**V1**	**19**	**30**	**44**	**44**	**98**	**50**	**l/s**	EN15251 : 2007 (Rp x NP + Ra x A)
	18	Air Changes per Hour	ACH	1,4	1,7	2,4	2,4	3,2	2,1	/h	V x 3,6 / Vol
	19	ventilation per person	Rp	7,0	7,0	7,0	7,0	7,0	7,0	l / s.p	EN 15251 - category 2
	20	ventilation unit area	Ra	0,70	0,70	0,70	0,70	0,70	0,70	l / s.m2	EN 15251 - category 2 ; low polluting
occupancy	21	occupant load, sens/p	OCP_S	75	75	75	75	75	75	W	ASHRAE Fundamentals
	22	occupant load, lat/p	OCP_L	55	55	55	55	55	55	W	ASHRAE Fundamentals
infiltration	23	infiltration airflow	INF	3,9	5,5	5,5	5,5	9,2	0,0	l/s	ACH_{INF} x Vol / 3,6
	24	infiltration air Changes per Hour	ACH_{INF}	0,3	0,3	0,3	0,3	0,3	0,0	/h	
loads	25	sensible load (clg design cdts)	L_{SENS}	800	1.200	1.500	1.800	3.000	1.400	W	from loads calcuation
	26	latent load (dehumd.dsg cdts)	L_{LAT}	94	165	275	275	643	220	W	NP x OCP_L + (INF/1000) x 1,2 x 2.500 x (HR_{ODA2} - HR_{IDA})
	27	**airflow for dehumidification**	**V2**	**15**	**27**	**45**	**45**	**105**	**36**	**l/s**	1000 x L_{LAT} / [1,2 x 2500 x (HR_{IDA} - HR_{SUP})]
Beam selection data	28	Beam chilled water temp. in	CWTin	16,0	16,0	16,0	16,0	16,0	16,0	°C	
	29	Safety temperature difference	dT	0,0	0,0	0,0	0,0	0,0	0,0	°C	CWTin - DP_{IDA}
	30	**primary airflow**	**V**	**19**	**30**	**45**	**45**	**105**	**50**	**l/s**	max (V1 ; V2)
	31	primary air temperature	DB_{SUP}	14,0	14,0	14,0	14,0	14,0	14,0	°C	
	32	primary air dew point	DP_{SUP}	13,0	13,0	13,0	13,0	13,0	13,0	°C	psychart
	33	primary air relative humidity	RH_{SUP}	94	94	94	94	94	94	%	psychart
	34	primary air humidity ratio	HR_{SUP}	9,4	9,4	9,4	9,4	9,4	9,4	g/kg	psychart
	35	cooling by air (primary airflow)	Cair	245	402	593	593	1.386	656	W	V x 1,2 x (DB_{IDA} - DB_{SUP})
	36	cooling by water (water coil)	C_W	555	798	907	1.207	1.614	744	W	L_{SENS} - Cair
	37	cooling by water (water coil)	C_W	69%	67%	60%	67%	54%	53%	%	C_W / L_{SENS}

Primary Air Calculation & Beam Specification

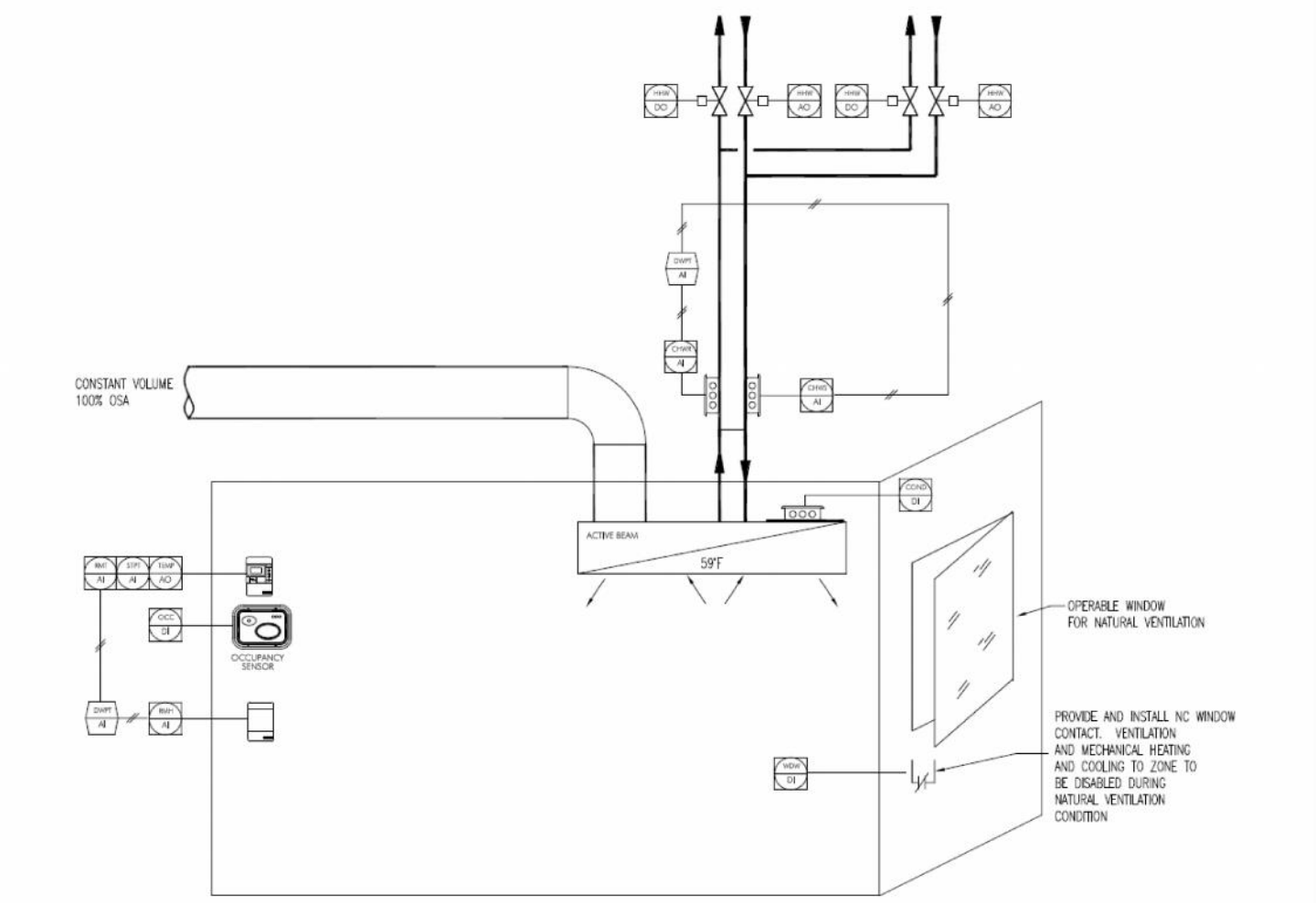
The use of the spreadsheet facilitates the exercise of trying different base conditions and optimizing the key design parameters, namely;

- CWT_{IN} , chilled water temperature supplied to the beams,
- dT, safety temperature difference,
- DP_{IDA}, indoor air dew point temperature,
- DP_{SUP}, primary air dew point,
- DB_{SUP}, primary air dry bulb temperature.

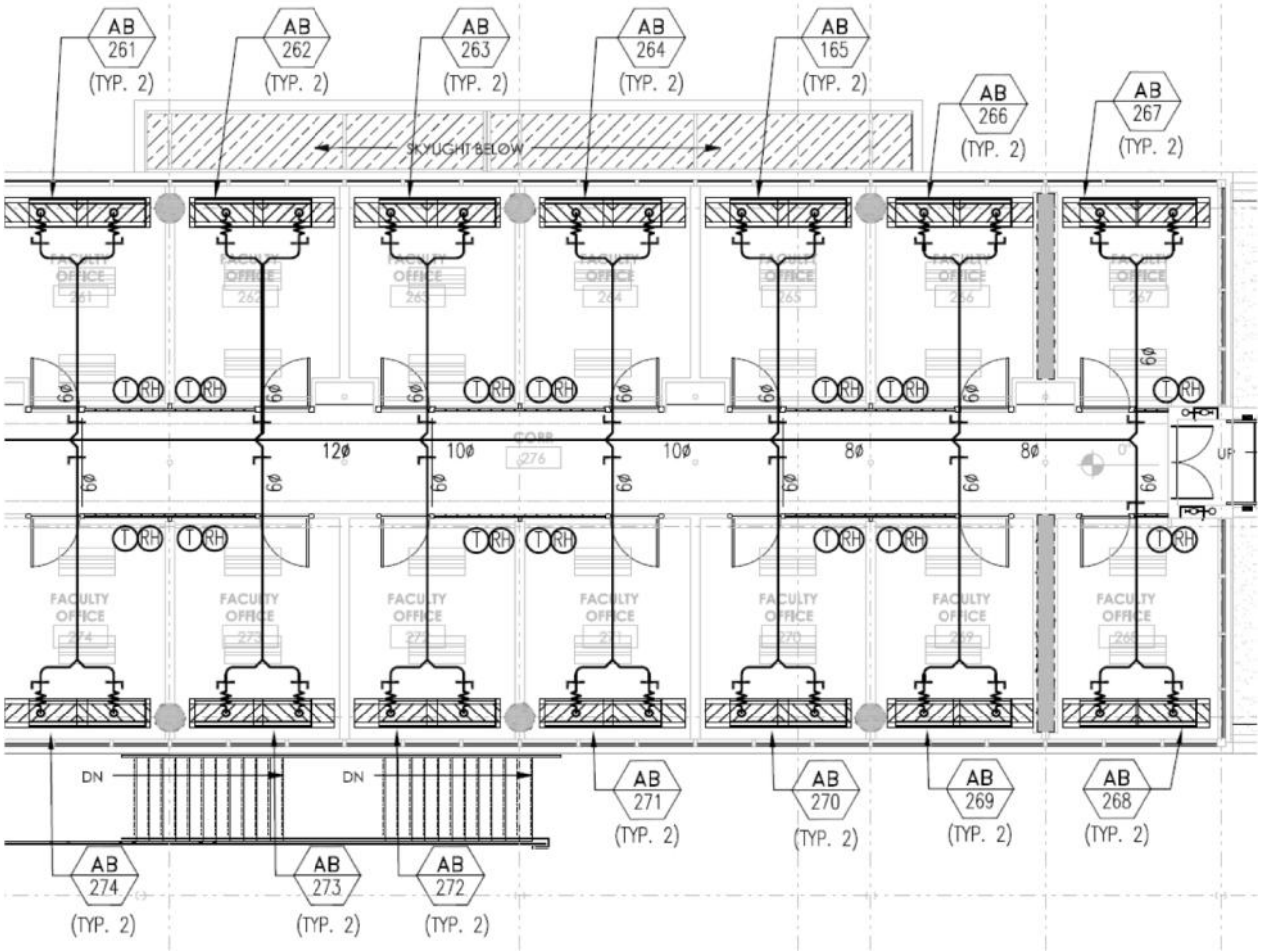
The actual beam selection may require the adjustment of some of the parameters and also reveal the need to increase the primary air flow in order to get to the required sensible cooling capacity in the room.

In any case the beam selection should maximize the amount of cooling done by the water coil. A good beam selection should have **over 65% cooling done by the water coil.**

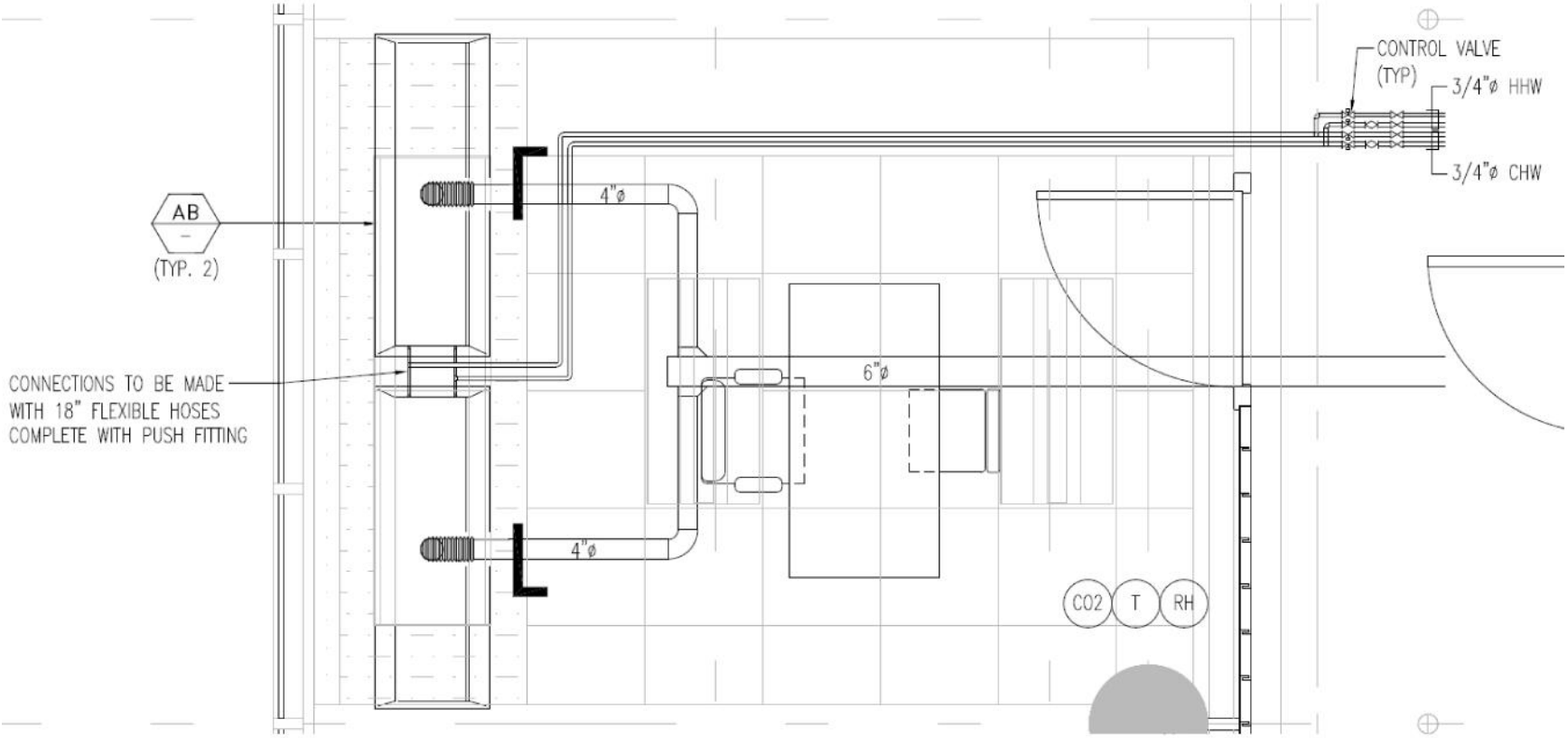
Controllability



Typical layout



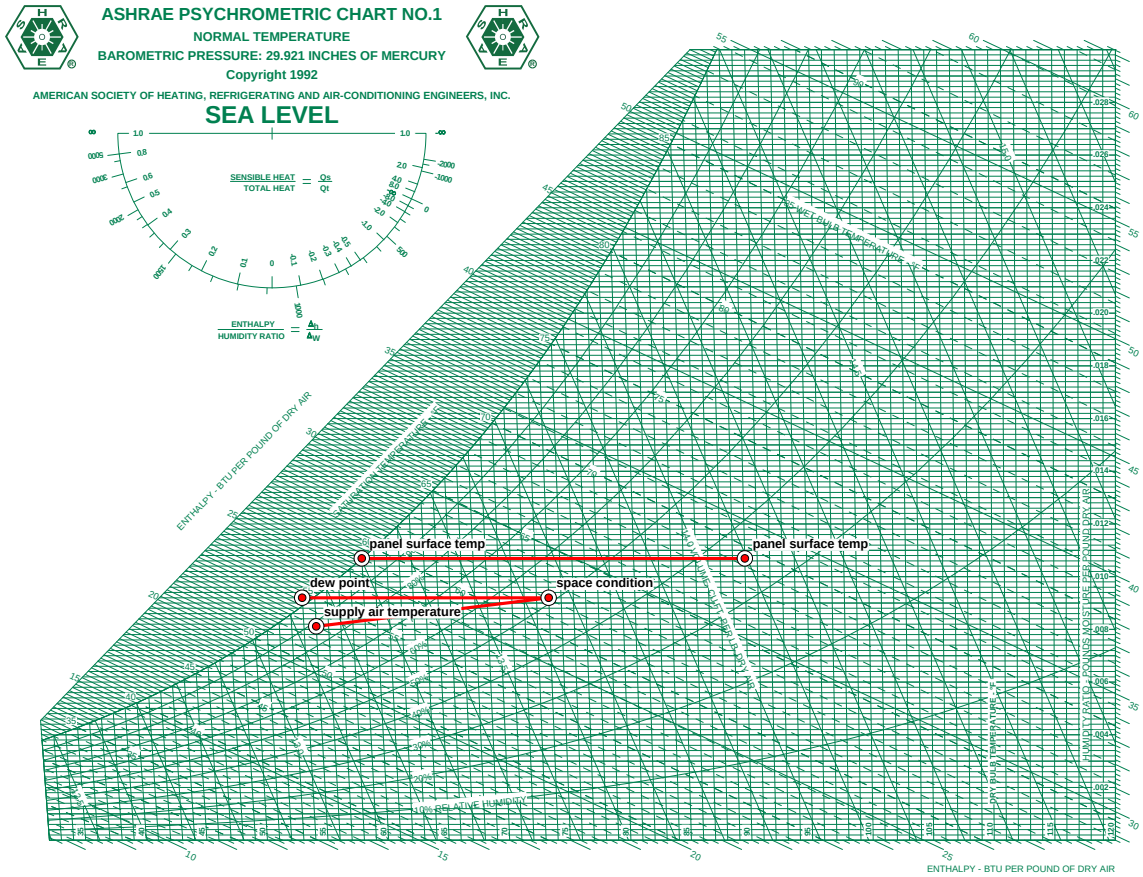
Controls


CONTROL VALVE
(TYP)
3/4"ø HHW
3/4"ø CHW
AB
(TYP. 2)
4"ø
6"ø
4"ø
CONNECTIONS TO BE MADE
WITH 18" FLEXIBLE HOSES
COMPLETE WITH PUSH FITTING
CO2
T
RH

Our preliminary design practice, standardization.

- Obtain space sensible cooling loads from Trace
- Calculate the latent gain from people
- Calculate the space humidity conditions from the supply air humidity ratio and the latent gain, plot this on a psychrometric chart
- Select a unit that meets your design criteria (use manufacturers tools if necessary)

Dew Point Control



Observations

- Active Beams are not the solution to the worlds energy problems.
- Active Beam applications need to be engineered
- Fundamental psychometrics and design knowledge are essential
- Active beams should not be used to try and keep up with the others

Where do the Energy Savings come from?

- A load is a load
- The kW's have to go somewhere
- Suggest modeling an active beam system as a four pipe fan coil system, with outside air volumes determined from separate calculations and fan power determined from separate calculations
- The possible chilled water advantage

Energy analysis

- Use of water to transport thermal energy;

Energy used to supply 1.000W cooling

description	symbol	cooling with water	cooling with air	units	formula/source
density	ρ	1.000	1,2	kg/m3	
specific heat	cp	4,2	1,0	kJ/kg.K	
delta T	ΔT	2	10	K	current value
cooling per (l/s)	cap	8,4	0,012	kW	ρ . cp . ΔT / 1000
flow per kW cooling	q	0,12	83,33	l/s	1 / cap
fan/pump pressure	P	200	1,5	kPa	current value
fan/pump efficiency (global)	η	0,55	0,55	-	current value
fan/pump power per kW cooling	**E**	**43**	**227**	**W / kWclg**	q . P / η

Air requires around 5 times more energy to supply the same cooling capacity

Adds 23% to the sensible cooling load

New York

Annual Electric Energy by End Use											
		Annual Source Energy		Annual Site Energy		Lighting	HVAC Energy			Peak	
		total	EUI	Electric	Nat Gas	Electric	Electric	Nat Gas	total	Electric	Cooling
Annual Energy Use (kWh)		Mbtu	kBtu/sf/yr	kWh	Therms	kWh	kWh	Therms	Mbtu	kW	tons
0	Base Design - VAV	29,992	167	2,594,809	34,236	599,160	711,876	8,412	3,271	1,025	456
1	0+Fan Coils	31,795	177	2,814,940	29,727	599,160	932,006	3,924	3,573	1,031	513
2	0+Radiant Ceiling	27,349	152	2,336,119	34,295	599,160	453,185	8,482	2,395	862	426
3	0+Active Beams	27,564	153	2,356,092	34,400	599,160	473,158	8,585	2,473	873	461
Incremental Savings											
1	0+Fan Coils	-1,803	-10.02	-220,131	4,509	0	-220,130	4,488	-302 (-9%)	-6 (-1%)	-57 (-13%)
2	0+Radiant Ceiling	2,643	14.75	258,690	-59	0	258,691	-70	876 (27%)	163 (16%)	30 (7%)
3	0+Active Beams	2,428	13.56	238,717	-164	0	238,718	-173	797 (24%)	152 (15%)	-5 (-1%)
Cumulative Savings											
1	0+Fan Coils	-1,803	-10.02	-220,131	4,509	0	-220,130	4,488	-302 (-9%)	-6 (1%)	-57 (-13%)
2	0+Radiant Ceiling	2,643	14.75	258,690	-59	0	258,691	-70	876 (27%)	163 (-16%)	30 (7%)
3	0+Active Beams	2,428	13.56	238,717	-164	0	238,718	-173	797 (24%)	152 (-15%)	-5 (-1%)

Los Angeles

Los Angeles											
Annual Electric Energy by End Use											
		Annual Source Energy		Annual Site Energy		Lighting	HVAC Energy			Peak	
		total	EUI	Electric	Nat Gas	Electric	Electric	Nat Gas	total	Electric	Cooling
Annual Energy Use (kWh)		Mbtu	kBtu/sf/yr	kWh	Therms	kWh	kWh	Therms	Mbtu	kW	tons
0	Base Design - VAV	29,779	165	2,679,658	23,422	599,160	796,725	124	2,732	938	391
1	0+Fan Coils	31,813	177	2,879,748	23,276	599,160	996,816	7	3,403	948	389
2	0+Radiant Ceiling	26,668	148	2,376,977	23,301	599,160	494,044	35	1,690	795	330
3	0+Active Beams	26,824	149	2,392,191	23,309	599,160	509,257	37	1,742	818	346
Incremental Savings											
1	0+Fan Coils	-2,034	-11.3	-200,090	146	0	-200,091	117	-671	-10	1 (0%)
2	0+Radiant Ceiling	3,111	17.35	302,681	120	0	302,682	89	1,042	144	61 (16%)
3	0+Active Beams	2,955	16.48	287,468	112	0	287,468	87	990	120	44 (11%)
Cumulative Savings											
1	0+Fan Coils	-2,034	-11.3	-200,090	146	0	-200,091	117	-671	-10	1 (0%)
2	0+Radiant Ceiling	3,111	17.35	302,681	120	0	302,682	89	1,042	144	61 (16%)
3	0+Active Beams	2,955	16.48	287,468	112	0	287,468	87	990	120	44 (11%)

Cost Experience

- Are active beam systems competitive with VAV or other alternatives?

Shortcomings

- Overcooling

Applications

- No Beams in meeting rooms
- Calculate latent space loads
- Determine fresh air supply

Last slide

- It is up to the Engineer of record as to what system is used

Thank You

- **Questions**

peter@petersimmonds.com

SISTEMAS DE ÁGUA GELADA

PROGRAMA BRASILEIRO DE ELIMINAÇÃO DOS HCFCs
Projeto para o Gerenciamento de Chillers

Apoio Institucional:

ASHRAE Brasil Chapter

ABRAVA – Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento

ABESCO – Associação Brasileira das Empresas de Serviços de Conservação de Energia

ABRAFAC – Associação Brasileira de Facilities

ANPRAC – Associação Nacional dos Profissionais de Refrigeração, Ar Condicionado, Ventilação e Aquecimento

ASBRAV – Associação Brasileira de Refrigeração, Ar Condicionado, Aquecimento e Ventilação

GBC BRASIL

BCxA – Building Commissioning Association – Brasil Chapter

SINDRATAR

Execução

SOMAR

Implementação

PNUD – Empoderando vidas. Fortalecendo nações.

Ministério do Meio Ambiente

Realização

GOVERNO FEDERAL BRASIL PÁTRIA EDUCADORA