



## **CRC TP Topic 5- The use of chilled beams in existing buildings and the new International GuideBook (ASHRAE-REHVA)**

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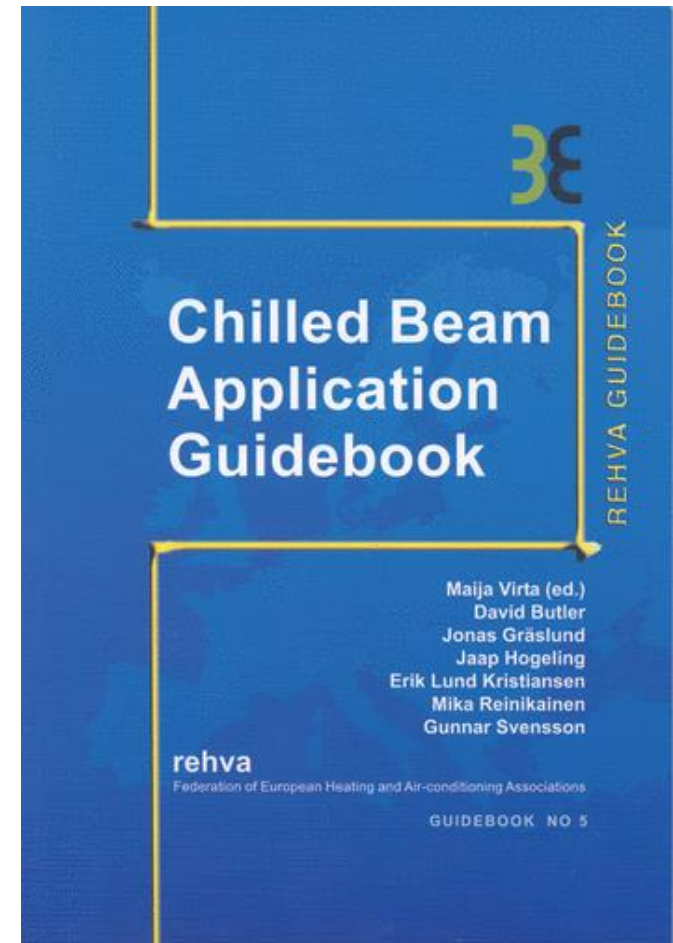
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# Learning Objectives

- Understand the advantages of the application of chilled beam systems in sustainable building renovation;
- Understand how a chilled beam system functions;
- Understand design considerations when determining whether a project is a good chilled beam candidate;
- Understand how to control chilled beam systems;
- Understand condensation risks and control strategies to prevent condensation;
- Understand how beam systems can reduce building energy consumption, maintenance and replacement costs.

# History

- REHVA Guide published in 2004
- ASHRAE intention to draft a guide
- Motivation to draft one book for the industry
  - Consistent
  - Updated
  - Range of experience



# History

- Committee formed at the Albuquerque meeting in 2010.
- Consisted of members of both ASHRAE and REHVA
  - Consultants (6)
  - Manufacturers (7)
- 10 face-to-face meetings
- Numerous teleconference meetings
- Publication submitted to ASHRAE at the New York 2014 winter meeting, in January
- Submitted simultaneously to REHVA

# Beam GuideBook Committee

ASHRAE	REHVA
Julian Rimmer (Chair), Price Industries	John Woollett (Chair), Swegon
Darren Alexander, Twa Panel Systems	Mick Holland, Ability Projects
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	Maija Virta
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# Beam Systems in renovation

The following features make beam systems a good candidate for building renovation:

- Requires relatively small floor to floor height;
- Requires small mechanical rooms;
- Can dismiss the application of a suspended ceiling (exposed multiservice beam);
- Does not require condensate drainage piping network at the room level (only in mechanical rooms).

# Renovation of old induction systems

In the renovation of buildings equipped with old induction systems (noisy and with very limited controllability) the application of contemporary induction units (chilled beams) can be a very cost effective solution.

The existence of buildings with still operable induction units after over 40 year of operation is a proof of the longevity of this type of equipment.

# Beam Systems and Sustainability

The following features make beam systems a relevant contributor for a sustainable building:

- Great energy efficiency minimizing energy use;
- Reduced maintenance requirements, minimizing consumable materials;
- Excellent occupant comfort;
- Long equipment lifetime, minimizing materials and energy use.

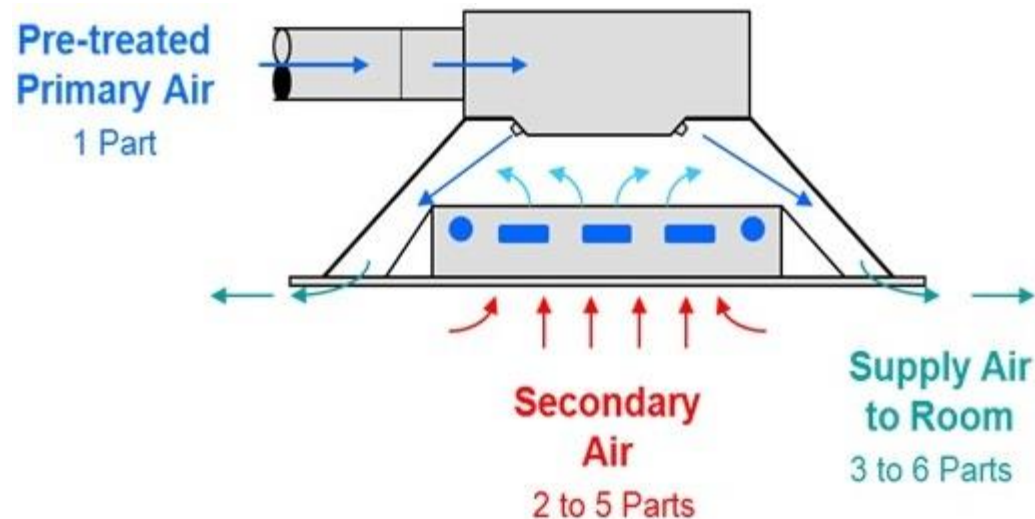
# Beam Systems and LEED

Beam systems can contribute to achieve the following LEED credits:

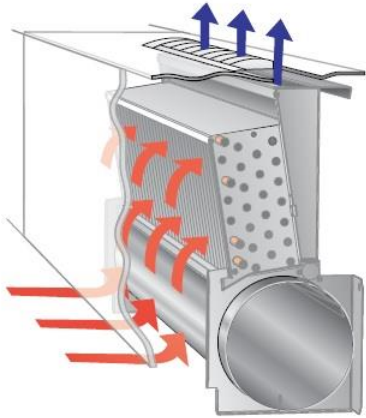
- EA-c 1, Optimize energy performance;
- EQ-c 2, Increased ventilation;
- EQ-c 7.1, Thermal comfort, design;
- EQ-c 6.2, Controllability of systems

# Active Beam Concept

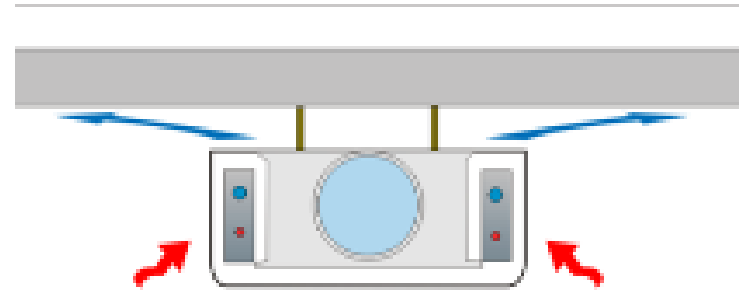
- Primary air is supplied to beam plenum and forced through jet nozzles
- Room air is induced and forced through water coil (cooling or heating)
- Mix of primary and cooled secondary air is supplied through an air diffuser



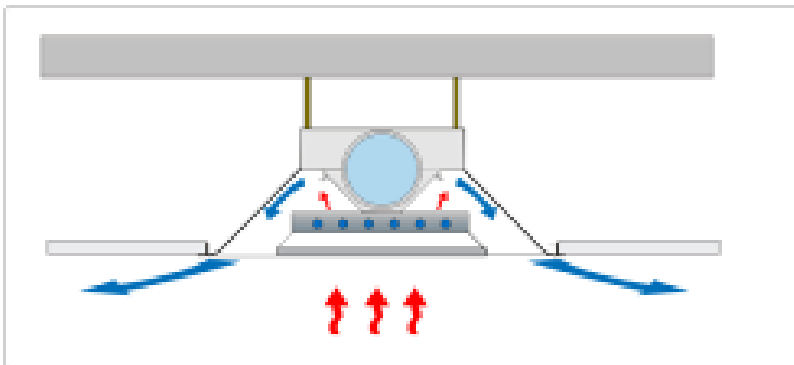
# Active Beam Designs



Perimeter wall  
instalation,  
under the  
window sill



Exposed installation

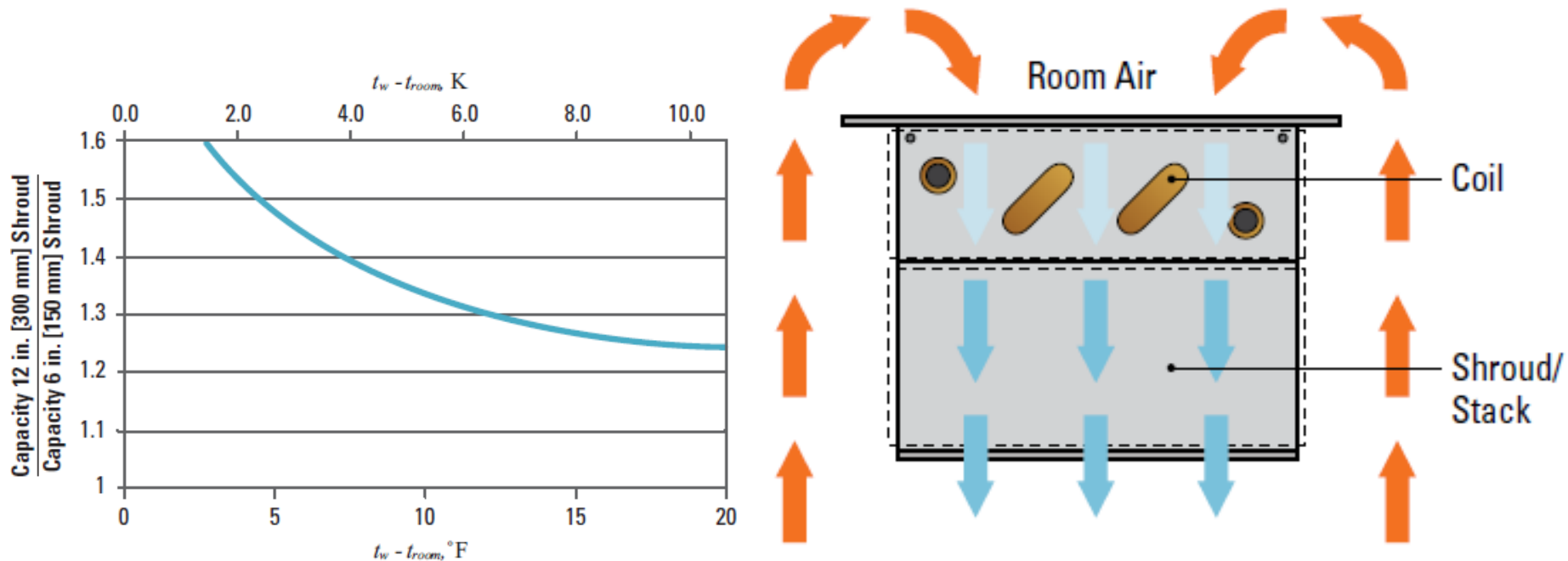


Recessed installation

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

# Passive Beam Concept

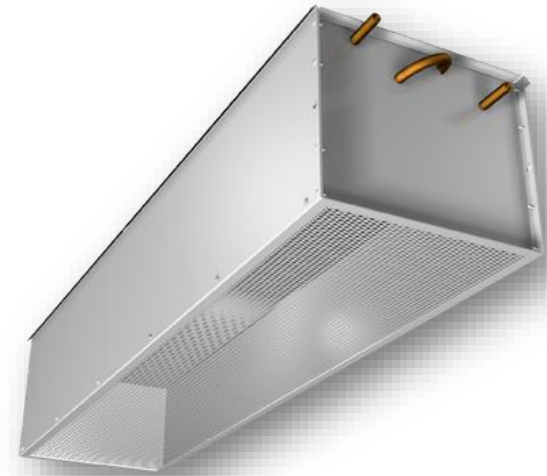
- Buoyancy forces promote the circulation of room air through the chilled water coil
- No primary air is supplied to the beam



# Passive Beam Concept

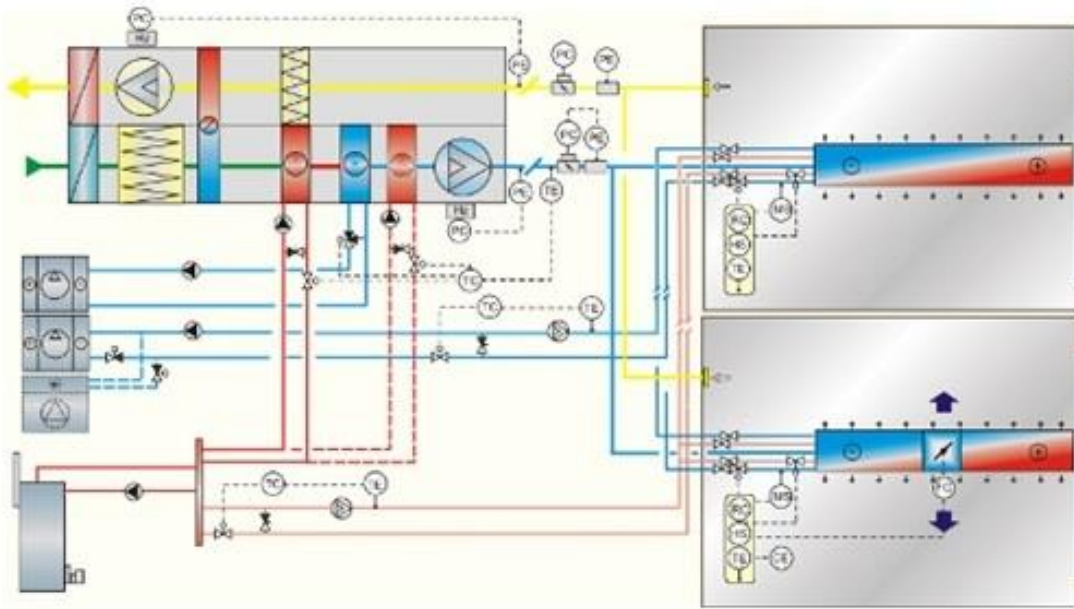


Passive chilled beam for  
recessed installation



Passive chilled beam for  
exposed installation

# Beam System concept



- Beam functions:
  - Room sensible cooling;
  - Room heating;
  - Room air distribution.
- Primary air system functions:
  - Ventilation;
  - Ventilation loads;
  - Room dehumidification (latent load);
  - Room sensible cooling (**small %**).

# Beam System concept

- Typical values:
  - Passive Beams up to 150 W/m;
  - Active Beams up to 180 W/m<sup>2</sup>;
  - Chilled water 14°C to 18°C;
  - Hot water 30°C to 45°C;
  - Primary air temperature 13°C to 21°C;
  - Beam plenum pressure 50 Pa to 250 Pa;
  - Room sensible cooling by the chilled beam water coil  $\geq$  60%;
- Non-condensing coils at the room level;
- Condensation prevention strategy required.

# Beam System Applications

The energy benefits of a Beam System are maximized whenever the following conditions are met:

- Moderate room sensible loads ( $<100\text{W/m}^2$ );
- Moderate and controlled room latent load;
- Low air-side load fraction;  
*(When a significant amount of primary air is required for sensible cooling, dehumidification or ventilation the energy benefit of a high temperature hydronic room cooling system is reduced)*

# Beam System Applications

Examples of applications:

Office Buildings

Hotel rooms

Patient rooms

Laboratories

Schools

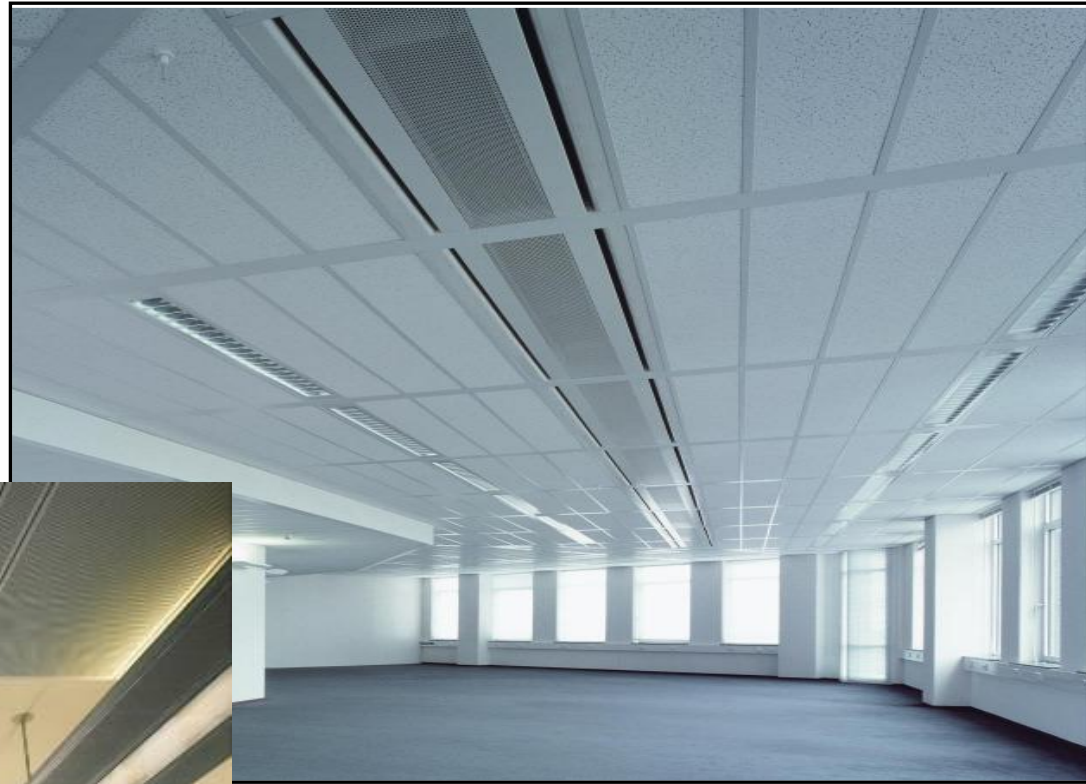
Retail

Beam systems are not well suited for places where humidity/latent loads are difficult to control or places with particularly high loads:

- Areas of ingress/egress of buildings
- Leaky buildings
- Auditoriums

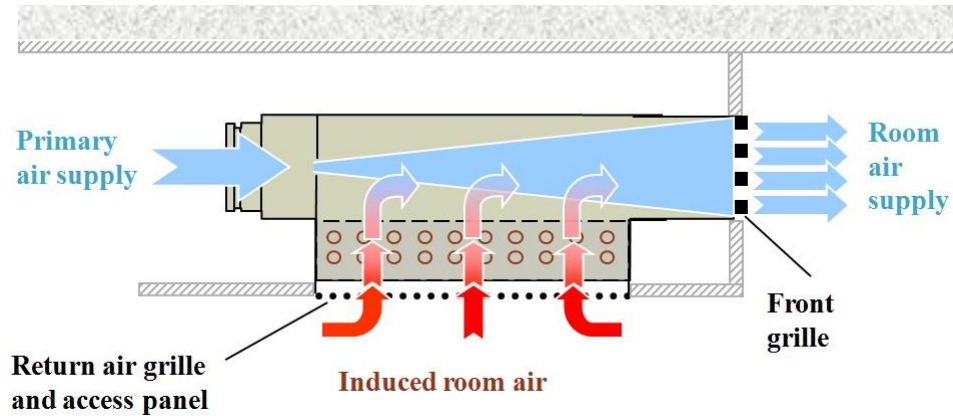
# Beam System Applications

**Recessed Active Beams  
installed in an acoustical ceiling**



**Exposed MultiService Passive  
Beam with integrated lighting**

# Beam System Applications



Hotel room



Lab Application



# Beam Systems in humid climates

- Active or passive beams operate at the room level
- When the building envelope has an adequate level of air tightness, **outdoor climate influences predominantly the operation of the primary air handling unit**
- In all climates, when operable windows are used, window switches should be installed discontinuing the water flow in the beam
- **Beam systems are adequate for humid climates**

# Control of Beam Systems

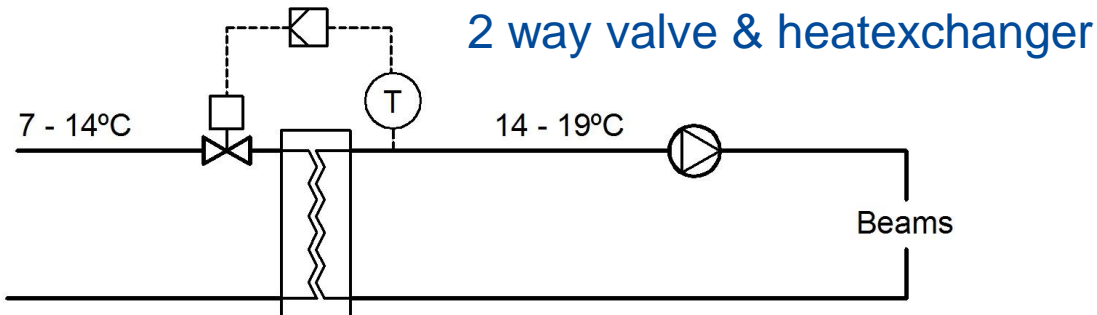
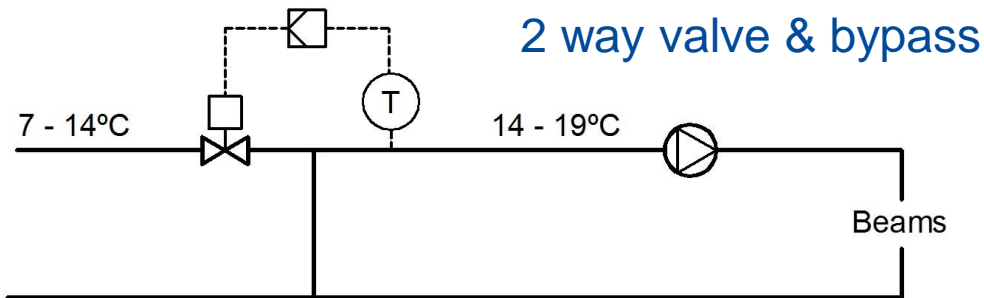
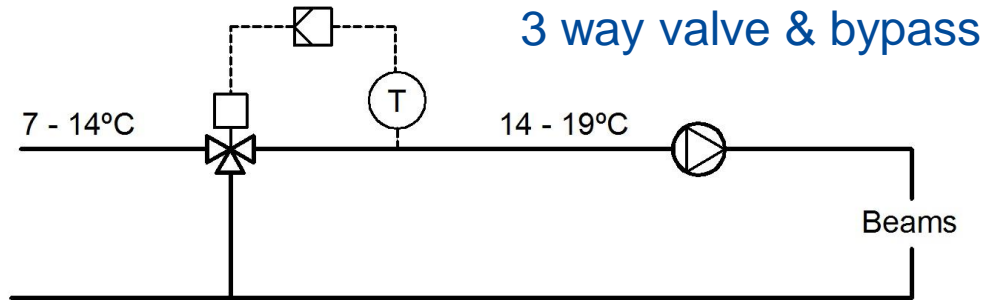
Beam System controls include the following:

- Zone control;
- Chilled Beam supply water temperature control;
- Primary air condition control;
- Condensation prevention.

# Zone Control

- The primary control of **space temperature** is normally accomplished by varying the water flow in the beam coil while maintaining a constant primary air temperature and flow rate
- Varying the primary airflow to the room, according to the actual occupancy (**DCV**), can significantly reduce the system energy consumption; by minimising the AHU energy consumption and reheat energy to avoid overcooling in low occupancy periods

# Chilled water temperature control



Quality chilled water temperature control is necessary to prevent condensation risk, maintaining chilled water temperature at or above indoor air dewpoint.

# Primary air condition Control

- Control of the building humidity level is paramount when beam systems are used
- Humidity control is solely provided by the primary air delivered by the AHU
- In order to avoid the risk of condensate formation on the beams, besides primary air temperature control, the AHU must condition the primary air so that the design primary air dew point is not exceeded

# Condensation prevention

The formation, and subsequent falling, of water droplets on the coil surface lags the onset of conditions that could cause condensation.

A rule of thumb from mock-up tests, which have forced condensation to form on the beam's coil surface, showed the **first visible droplet** on the inlet cold pipe to the coil was detected at approximately **2°C** below the indoor air dew point (DP).

# 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;

# Energy analysis

- Use of dynamic building energy simulation software,
- Fully know and understand the technology to be simulated,
- Deeply know and understand the calculation method used in the software,

# Energy analysis

- Specific features that may reduce energy consumption,
  - Higher CWT (13– 17°C) (55-63°F)
  - Lower HWT (32 – 45°C) (90-113°F),
  - Water to transport thermal energy,
  - Absence of excessive uncontrolled dehumidification,
  - Energy efficient room air distribution,
- Specific features that may increase energy consumption,
  - Low CWT temperature differential ( $\Delta T \sim 2^{\circ}\text{C}$ )

# Energy analysis

- Use of higher CWT (13– 17°C) (55-63°F) opportunities;
  - Dedicated chillers (high EER temperature program),
  - Water free-cooling (without compressors) using,
    - Cooling tower,
    - Dry-cooler,
    - Geothermal sources,
  - Increase of CW deltaT in the chillers.

# Energy analysis

- Use of lower HWT ( $32^{\circ}$ –  $45^{\circ}\text{C}$ ) ( $90$ - $113^{\circ}\text{F}$ ) opportunities;
  - Condensation boiler,
  - Heat pump (high COP temperature program),
  - Reclaim heat (example; from Data Center cooling),
  - Geothermal sources,

# 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	$\rho$	1.000	1,2	kg/m <sup>3</sup>	
specific heat	$c_p$	4,2	1,0	kJ/kg.K	
delta T	$\Delta T$	2	10	K	current value
cooling per (l/s)	cap	8,4	0,012	kW	$\rho \cdot c_p \cdot \Delta T / 1000$
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)	$\eta$	0,55	0,55	-	current value
<b>fan/pump power per kW cooling</b>	<b>E</b>	<b>43</b>	<b>227</b>	<b>W / kWclg</b>	$q \cdot P / \eta$

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

Adds 23% to the sensible cooling load

# Energy analysis

- Minimization of latent cooling;
  - In systems using condensing zone coils (wet), dehumidification is often excessive.
  - Dehumidification at the zone coil is usually uncontrolled and increases when the coil surface temperature decreases
  - In beam systems, zone coils are dry and **dehumidification is performed at the AHU in a controlled manner.**

# Energy analysis

- Building simulation model;
  - Make sure all the features are accounted for in the calculation,
  - No building simulation software includes all the possible variations that may occur in an hvac design,
  - Frequently, “workarounds” are necessary to simulate specific features of hvac systems/equipments,
  - Input must be carefully reviewed bearing in mind the software’s calculation methodology,
  - Output must be carefully analysed; “***assume the simulation is wrong until proven right***”

# Capital Expenditures (CAPEX)

- Installation costs,
  - Detailed comparison with alternative systems,
- Replacement costs,
  - 20 years lifetime for beams,
- Other costs,
  - Not directly related to the HVAC system

# Capital Expenditures (CAPEX)

- Opportunities for other costs reduction,
  - Reduced floor-to-floor height,
  - Relatively small mechanical rooms,
  - Deletion of architectural ceiling,
  - Integrated services (multi-service beam),

# Operating Expenditures (OPEX)

- Energy costs,
  - Opportunities related to the use of Beam Systems,
- Maintenance costs,
  - Opportunities related to the use of Beam Systems,

# Operating Expenditures (OPEX)

- Features that reduce maintenance costs;
  - No fans&motors at the room level,
  - No filters at the room level,
  - Dry coils at the room level,
  - No condensate drain pans at the room level,
  - No condensate drain piping at the room level,
  - Centralized location of all equipments that require frequent maintenance.

# Operating Expenditures (OPEX)

- Typical maintenance routines,
  - Coil cleaning (time interval from 3 to 5 years)
    - Dry cleaning with vacuum equipment,
    - Removal of suspended ceiling not necessary,
    - Elevation equipment not necessary
  - Control system operation checked (annually)

# Acknowledgements

This presentation was prepared based on the work of the BG Committee but specially on past presentations produced by:

- Carlos Lisboa;
- Chris Lowel;
- Ken Lowdermilk;
- Julian Rimmer;
- Rafael Úrculo;
- Risto Kosonen.

# Questions?

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