An Introduction to Chilled Beams and Ceilings

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Version 1

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1 Introduction

Chilled beams and radiant chilled ceilings have been with us for many years. However, during the last decade, the technology has been refined and improved and has been more widely applied.

Building services design engineers and end users have embraced the aesthetic, environmental and comfort attributes of an approach that is now generally regarded as the most space efficient and environmentally friendly method of heating and cooling a building.

As well as reducing energy consumption, chilled beams and ceilings improve comfort levels by lowering the potential for draughts and cutting out the intrusive noise and aesthetic problems associated with more conventional solutions, such as mechanical ventilation and air conditioning.

At a time when sustainability is higher up the building engineer's agenda than ever, a system that uses minimal energy to achieve excellent comfort conditions, involves no moving parts, has a long life-cycle and is designed for decommissioning with 100 per cent recyclable components ticks almost every box.

Building system designers have the increasingly onerous task of reducing overheating in sealed buildings while also meeting increasingly stringent energy efficiency targets laid down by continually changing legislation and more energy conscious clients. In 2006, the revised Part L of the Building Regulations put the focus firmly on how services perform in cooling mode as well as heating for the first time so forcing designers to get serious about properly integrated design solutions and this helped to drive demand for chilled beams and radiant chilled ceilings.

In 2010, the latest version of the regulations calls for a further 25 per cent improvement in energy efficiency. In the future, it is anticipated that there will be further energy reduction targets with further issues of building regulations expected in 2013 and 2016 leading to the Government target of a net zero regulated carbon requirement by 2019.

All of this creates an even more persuasive case for chilled beam and chilled ceiling technology.

The fact that chilled beams and chilled ceilings are water-based systems also makes them environmentally attractive, particularly as the use of synthetic refrigerants in air conditioning is under greater scrutiny than ever with the advent of the EU's ozone depleting substances legislation and the restrictions created by the F-Gas Directive.

Also, because they are unobtrusive installations, they free up much more valuable office space for occupation and use, as well as offering total flexibility if the end user wants to reconfigure the occupied space to cater for changes in use.

Ever more innovative designs, including the use of ground source heat pumps in tandem with chilled beams and radiant chilled ceilings, are improving the sustainability of building services systems by reducing the amount of energy needed to heat or cool water – a primary source of building-related greenhouse gas emissions.

Many designers also incorporate heat recovery devices and inverter drives on the fans and pumps to further enhance the sustainable operation of the complete system. The savings generated in this way have knock-on benefits throughout the whole building reducing the energy consumption of chillers and boilers and extending their operating life.

Chilled beams and chilled ceilings are not appropriate for every building project, but there are a growing number of applications where they are ideal – particularly in commercial office developments, hotels and hospitals. This guide will help you decide whether they are the right solution for you and will point you towards further sources of technical advice from manufacturers and specialist designers.

We hope you find it useful and look forward to working with you in the future to deliver sustainable heating and cooling solutions.

2 Scope

Chilled beams and radiant chilled ceilings have been around for a long time. The first models were developed in 1962 for the Shell Oil Headquarters, London, which utilised water from the River Thames to cool down the building (via a secondary heat exchanger in the plant room) but although this solution was revolutionary and extremely efficient, Chilled Ceilings struggled to capture the imagination of many specifiers in the UK, however the rest of Europe capitalised on the benefits of this technology. Nowadays, with a range of recent energy saving legislation and new chilled technologies being developed, both chilled beams and chilled ceilings have captured more interest.

Chilled beams and chilled ceilings have distinct advantages over the alternative air conditioning technologies. For example, they do not require a secondary fan so they are inherently more energy efficient than their main rivals – fan coil units. An additional benefit is chilled beams and chilled ceilings use higher chilled water flow temperatures than fan coil units, which means there is a significant part of the year when chillers do not need to be working and free cooling is available.

However, energy consumption is not the only advantage of chilled beams and chilled ceilings. Their whole life costs are also lower than fan coil units, they contain no moving parts and are therefore more reliable and less noisy, they are maintenance free, they have a long life expectancy and no condensate containment provision is required.

The technology has still not achieved its full potential and is often overlooked for projects where it would be the best suitable system. This is largely due to a lack of knowledge and understanding across the building sector and has flagged up the need for a better flow of information between suppliers, consulting engineers, architects and contractors.

This guide sets out to plug part of that information gap. It provides a comprehensive overview of the main features of the technology along with the key selection criteria, design decisions and practical steps for installation, commissioning and maintenance.

It is designed to be a very practical document providing a valuable working introduction for the non-specialist. It will also serve as a generic overview that provides sufficient information to address key considerations, but avoids the detailed advice that should be provided by the specialist manufacturer.

3 Technical description

Overview

Water offers a more energy efficient way of distributing energy in the form of heating and cooling around a building than 'all air' systems because of its high specific heat capacity and thermal conductivity.

This section is intended to give an overview of the following water-based systems:

- ***Chilled ceilings (including Ceilings and Rafts / Sails).***
- ***Chilled beams (including Active and Passive).***
- ***Other systems (including Multi-service Chilled Beams 'MSCBs' and four way discharge cassette chilled beams).***

Chilled beams and chilled ceilings require a relatively modest cooling water temperature (14–17°C), which can be obtained using natural cold water storage or free cooling from outside air over periods of the year depending on climate. Also, when mechanical cooling is used, a better energy performance can be achieved because of the higher chiller CoP (coefficient of performance).

Where chilled beams are used for heating, the situation is similar in that it is possible to use low temperature heat sources or heat pumps with water flow temperatures of typically 30–45°C.

Chilled Ceilings

3.1 Radiant chilled ceilings

Radiant chilled ceilings usually incorporate a chilled water coil or element into the rear of the ceiling finish material. Typically, this means copper pipe matrix on the rear of metal ceiling tiles or panels. Insulation is usually applied on the upper surface of the chilled ceiling, as the useful cooling is required in the space below the ceiling.

As chilled water passes through the coil, it offers a cool ceiling surface that provides space cooling by both radiation and convection.

'Radiant cooling' involves the direct absorption of heat radiated from warm surfaces within the room, which occurs when there are cooler surfaces visible to the warmer surfaces. This type of system results in low air velocity with an even temperature distribution in the occupied zone, thus providing very good comfort levels.

Radiant chilled ceilings provide an architecturally acceptable surface, into which a range of services can be fitted. They can also usually be accommodated with shallow ceiling voids, so are suitable when vertical space is restricted. A separate ventilation system is required to supply fresh air to the space.

Figure 1 shows a lower surface perspective with a cut away showing the chilled ceiling elements bonded to the rear surface of the panel/tile.

Figure 1: Radiant chilled ceiling panel / tile assembly (bonded type)

Figure 1a shows a ceiling panel / tile where the chilled waterway is a "lay-in" part of the ceiling/tile.

Figure 1a "Lay-in" radiant ceiling panel/tile

Figure 2 shows how chilled water elements are inter-connected and connected to the water flow and return distribution pipe-work. The same principle can apply to both "Bonded" and "Lay-in" panels/tiles.

Figure 2: Radiant chilled ceiling panels/tiles interconnected as a typical arrangement

3.2 Radiant chilled ceilings (plaster finish)

Small-bore diameter plastic capillary coils are secured to the ceiling or wall structure and completed with a plaster finish. A special thin plaster is required to minimise the effects of a lower thermal conductivity.

3.3 Radiant and convective chilled rafts / sails

Radiant and convective chilled rafts or sails incorporate a chilled water coil or element onto the rear of large flat panels which are suspended below the soffit or ceiling. There is no insulation fitted to the rear of the panel as the cooling device is within the room space and all cooling (radiation and convection) is useful cooling (*see Figure 3*).

As chilled water flows through the coil, the lower surface of the raft or sail acts in precisely the same way as a radiant chilled ceiling with both radiant and convective cooling. The air above the raft or sail is also cooled and this provides additional convective output as it flows down over the edges of the rafts or sails.

The shape and size of rafts or sails can be varied to meet architectural requirements and services can easily be integrated. As the gap required above the raft or sails is small, they are suitable where vertical space is restricted. Sails can also be used for efficient radiant heating.

Figure 3: Radiant chilled rafts/sails

3.4 Convective chilled ceiling systems

These systems typically comprise a framework of angled fins (usually aluminium) with a chilled water pipe or water way (usually copper) integrated into the centre of each angled fin (*see Figure 4*).

There is thermal transfer from the water to the copper to the aluminium, thus cooling the fins. As a result of this, a greater proportion of cooling is achieved by air convection through the angled fins rather than by direct radiation.

This type of system can give higher cooling levels than a normal radiant system, but less than a Passive Chilled Beam.

Figure 4 Convective ceiling system

Table 1: Performance and characteristics

A summary of the characteristics of chilled ceiling systems can be found in the table below.

Characteristic		Radiant ceiling Lay-in /bonded (Section 3.1)	Plaster finish (Section 3.2)	Radiant/convective rafts/sails (Section 3.3)	Convective systems (Section 3.4)
Potential cooling capacity *	W/m² active area	60/90	55/65	80/120	110
	W/m² floor area	48/72	44/52	54/80	88
Ceiling tiles	Material	Alu/steel perforated	Special plaster	Alu/steel perforated or plain	Alu/steel open slats
Design		For use with conventional lay in tiles	Special plaster	Large flat panels suspended from soffit or slab no insulation rear of panels	Not for use with conventional suspended ceilings
Acoustics	Acoustic absorption	Good	Poor	Separate system	Separate system
	Room to room attenuation	Good	Good	Separate system	Separate system
Important Considerations	Thermal performance	Water quality – See section 9.3.3	Need special thin plaster	Clearance between soffit and rear of panel also clearance between adjacent panels	Return air gap around ceiling perimeter
Comfort Conditions		Excellent	Excellent	Good	Good
Relative cost of system		Medium	Medium/High	Medium	High

**** Based on:***
A) BS.EN14240
B) Temperature difference room to mean water temperature 8°K
C) Water flow return temperature difference 2°K
D) Room temperature 24°C
E) Water mean temperature 16°C
F) Active ceiling area as percentage of total ceiling area 80% except Rafts and Sails which are 67 per cent

Chilled beams

The basic thermal transfer component for chilled beams is a fin and tube heat exchanger, often referred to as coils. Rows of interconnected copper pipes are usually bonded to aluminium thermal conducting fins. This arrangement is then mounted in a sheet metal casing, which can either be:

- Freely suspended from a soffit, or
- Installed above a perforated metal ceiling (passive beam only), or
- Integrated flush into a suspended ceiling system.

Chilled beams work using convection rather than radiation. Because of the larger fin surface area, a higher thermal performance can be achieved with chilled beams as opposed to chilled ceilings. However, care needs to be taken in the selection process to ensure that high air velocities are not created in the occupied zone.

3.5 Passive chilled beams

Passive chilled beams work using natural convection. Warm air rising up in the space passes over the top and into the passive chilled beam. As the air between the aluminium thermal conducting fins is cooled, it becomes denser and returns, due to negative buoyancy, downwards to the space below (*see Figure 5*).

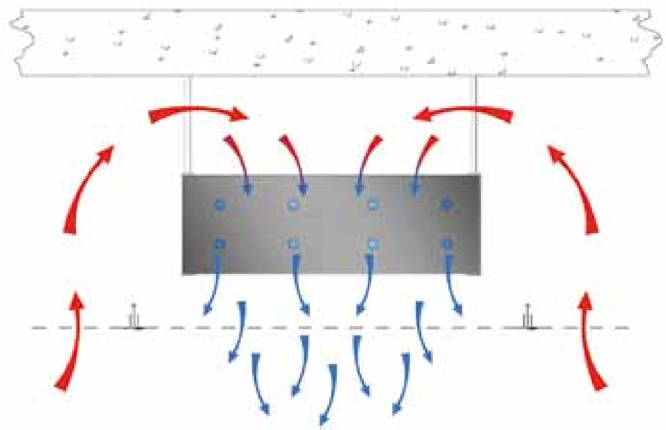


Figure 5: Passive chilled beam

Good air circulation is essential for the operation of passive chilled beams. Sufficiently large openings above the passive beam casing or ceiling system must be provided to allow air to circulate properly.

Passive chilled beams are arranged at regular intervals along the ceiling plane to provide uniform cooling to the occupied space below.

The location of passive chilled beams at the perimeter of a building with a large percentage of glazing can, particularly in the summer, benefit from the thermal convection created on the inside surface of the glazing (*see Figure 6*). This can enhance the cooling capacity of the passive chilled beam because the greater the air flow over the beam, the greater the cooling output.

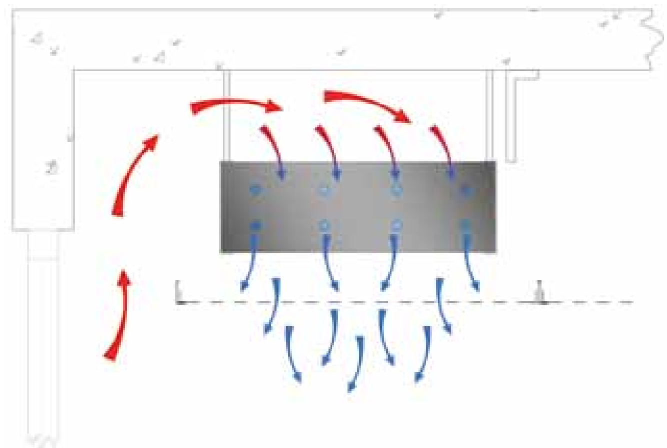


Figure 6: Perimeter passive chilled beam

It is important to note that with convective only passive chilled beams care must be taken in beam selection to ensure that the air velocities entering the occupied zone do not create draughts.

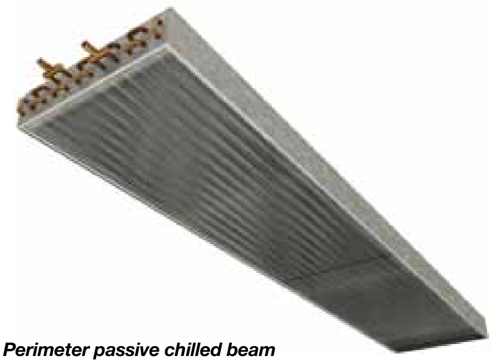


Figure 7 : Perimeter passive chilled beam

3.6 Radiant / convective passive chilled beams

This system comprises copper pipes contained within aluminium heat exchanger fins to increase visible surface area for radiant absorption (*see Figures 8, 9 & 10*).

The surfaces of the fins are painted and the system cools through a combination of natural convection (typically 65 per cent) and radiant exchange (typically 35 per cent). These systems deliver similar cooling duties to traditional “convective-only” passive chilled beams, but with reduced air velocities below the beam for increased thermal comfort.

These systems are usually painted black and mounted in the ceiling void above a perforated metal ceiling (see Figure 9), although the product can also be exposed from the structural slab or incorporated within multi-service chilled beams (*see Section 3.10*).

Again it is important to note that with convective chilled beams care must be taken in beam selection to ensure that the air velocities entering the occupied zone do not create draughts

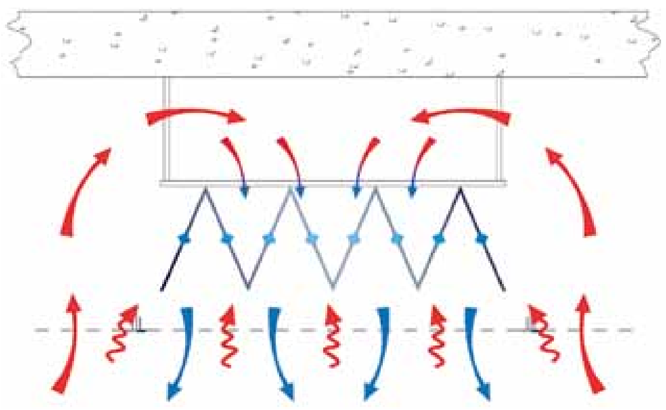


Figure 8: Radiant/convective beam above perforated ceiling

Figure 9: Radiant/convective beam above perforated ceiling

Figure 10: Radiant / convective passive chilled beam

3.7 Active chilled beams

Active chilled beams incorporate a primary air supply to enhance and control the induction of air through the coil. There is normally some form of primary air duct or plenum running along the length of the beam. This allows the primary air to be discharged into the beam, usually through nozzles, enhancing the induction of room air through the coil (*see Figure 11*).

The primary air is then mixed with the cooled air before being discharged into the space through integral slots. Like passive beams, active chilled beams are also arranged at regular intervals along the ceiling to provide uniform cooling to the occupied space.

Active chilled beams can also incorporate a separate copper pipework circuit for warm water to circulate through the same aluminium fins as used for cooling, thus enabling the chilled beam to provide heating as well as cooling.

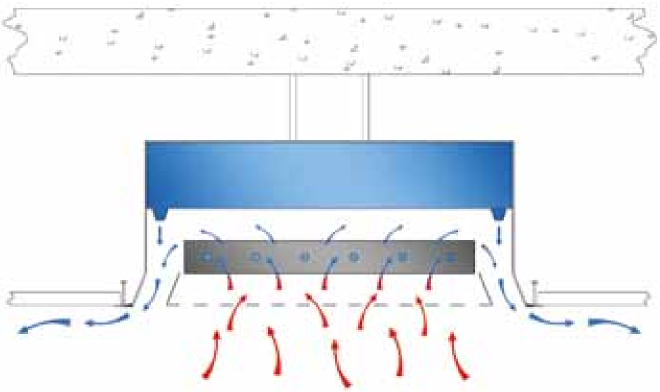


Figure 11: Active chilled beam

Figure 12: Two way discharge active chilled beam

3.8 Closed active chilled beams

Closed active chilled beams induce air directly from the space into the active chilled beam i.e., the whole system is self-contained and it does not depend on using air from the ceiling void (*see below*).

Closed active chilled beams typically have a two way discharge when in linear format but are also available with one way and four way discharge in modular format (*see Figures 12–17 respectively*). Discharge is horizontal in the presence of a ceiling surface.

Figure 13: One way discharge active chilled beam

Figure 14: Four way discharge active chilled beam

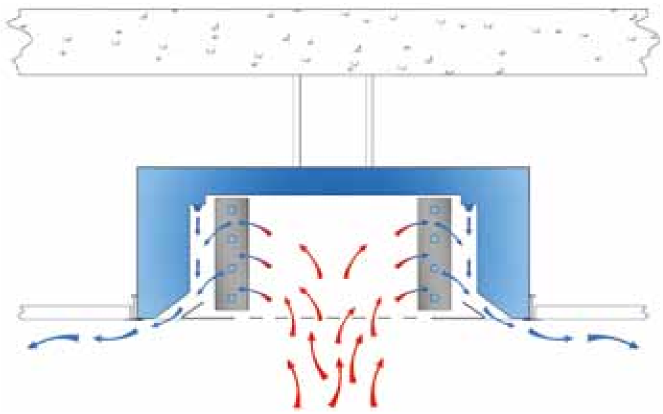


Figure 15: Closed active chilled beam with two way discharge

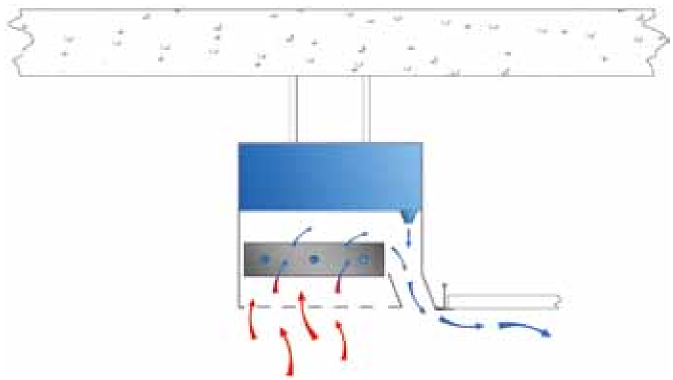


Figure 16: Closed active chilled beam with one way discharge

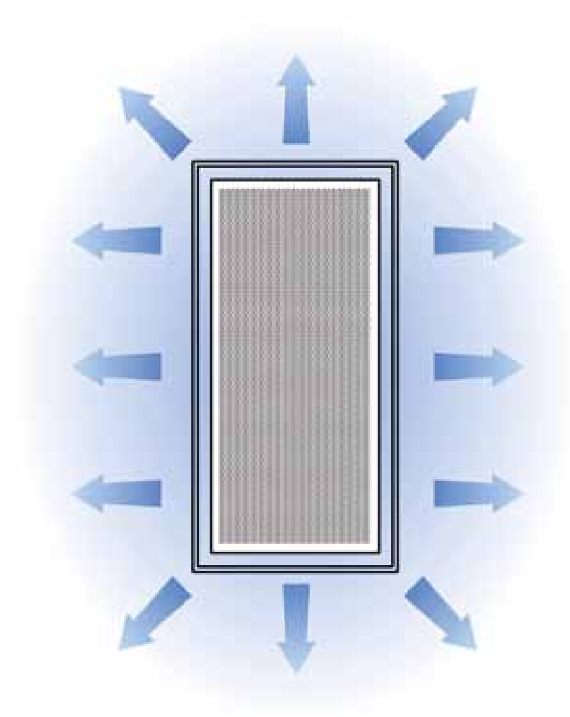


Figure 17: Closed active chilled beam with four way discharge.

3.9 Open active chilled beams

In this case, the room air enters the coil from the ceiling void (*see Figures 18 and 19* for two-way and one-way discharge respectively)

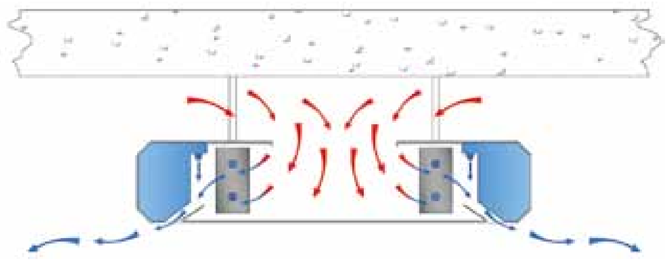


Figure 18: Open active chilled beam with two-way discharge

Again, it is critical to ensure that air has free access to the coil. Typically, as with all active beams, slots are used to provide a one or two way horizontal discharge in the presence of a ceiling surface.

If this type of system is used with a suspended ceiling, it is imperative that there is sufficient open area in the ceiling to allow room air to pass into the ceiling void. If this area is too small, the beam will not induce an adequate amount of air and the cooling capacity will be reduced.

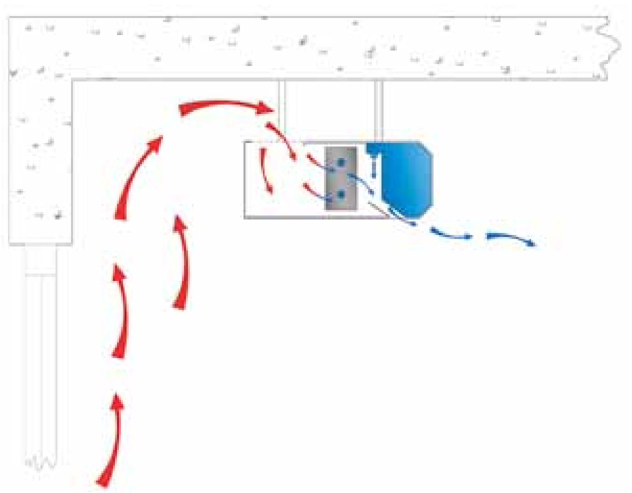


Figure 19: Open active chilled beam with one-way discharge

Table 2: Performance and characteristics

A summary of the characteristics of passive and active chilled beam systems can be found in the table below:

Characteristic		Passive 95% Convection (Section 3.5)	Passive 65%Convection 35% Radiant Absorption (Section 3.6)	Closed active (Section 3.8)	Open active (Section 3.9)
Potential cooling capacity *	W/m Cooling	≤ 225 W/m	≤ 300 W/m	≤ 500W/m	≤ 550 W/m
	W/m² Cooling	≤ 75 W/m²	≤ 100 W/m²	≤ 167 W/m² – See Note 8	≤ 183 W/m² – See Note 8
Potential heating capacity (both air and waterside heating)	W/m Heating	N/A	N/A	≤ 150W/m	≤ 150 W/m
	W/m² Heating	N/A	N/A	≤ 50 W/m²	≤ 50 W/m²
Installation location	Above ceiling	Yes	Yes	No	No
	In ceiling	Yes	Yes	Yes	Yes
	Below slab free hanging	Yes	Yes	Yes – See Note 9	Yes – See Note 9
Air circulation	Air entry	Grille / opening	Perforated tile	Grille integral in unit	Grille / opening
	Air discharge	Vertical	Vertical	Horizontal	Horizontal
Functions	Cooling	Yes	Yes	Yes	Yes
	Heating	No	No	Yes	Yes
	Ventilation	No	No	Yes	Yes
Noise	Air flow	Very low	Very low	Low/Medium	Low/medium
Important considerations	Entry area for induced air	Unit top surface area	Unit top surface area	Built into design	To manufacturer's requirements

**** Based on:***
A) BS.EN14518 Passive beams, BS EN15116 Active beams
B) Temperature difference room to mean water temperature = 8°K
C) Water flow return temperature difference = 2°K
D) Room temperature 24°C
E) Water mean temperature 16°C
F) Chilled beam pitch 3m

Notes

1. Thermal performance will, in the case of active beam, be influenced by the primary air flow and temperature. Depending on selection, output will differ.
2. Greater outputs can be achieved at the perimeter zone.
3. Passive chilled beam performance – The maximum cooling effect of up to 225 W/m applies to passive beams (circa 95 per cent convective elements) and is based upon comfort criteria as recommended within BS EN ISO 7730 (PPD < 15 per cent).
4. Convection only passive chilled beam designs are capable of higher levels of cooling (greater than 225W/m), however, careful consideration should be given at design stage to ways to limit draught and guarantee occupant comfort; the chilled beam conditioned air discharge, when in excess of 225 W/m, should be introduced in areas deemed outside that of the normal occupied zone (such as within 0.6m of the façade as referenced in ASHRAE 55 and PD CR 1752:1999).
5. When passive chilled beams with a higher percentage of radiant absorption are providing above 300w/m cooling, care should be taken to ensure that comfort criteria is within that shown in BS EN ISO 7730 (PPD< 15%).
6. Active chilled beam heating performance – The maximum heating effect of up to 150 W/m applies to active chilled beams and is based upon comfort criteria as recommended within BS EN ISO 7730 (PPD < 15 per cent).
7. Active chilled beam designs are capable of higher levels of heating (greater than 150W/m). However, careful consideration should be given at the design stage to ways to ensure acceptable levels of stratification within the occupied zone.
8. It should be noted that the "Potential Cooling Capacity" of active chilled beams have been stated as a combined "waterside" and "airside" cooling, where as the Passive beams have only been stated as "waterside". As such further cooling from the separate supply air delivery system should be taken into consideration when comparing Passive vs Active chilled beam solutions.
9. If Active beams are installed "free hanging" below a ceiling and / or roof soffit, there must be some form of extension to the discharge sides of the active beam for a negative pressure to be created at the point of air discharge into the space so that a coanda effect is created for horizontal discharge. Ordinarily these side profiles incorporate luminaires as associated with Multi Service Chilled Beams (MSCBs).

Other systems

3.10 Multi-service chilled beams

Multi-service chilled beams (MSCBs) – sometimes referred to as integrated service modules (ISMs) – combine chilled beams with additional building services into one module (*see Figure 20*).

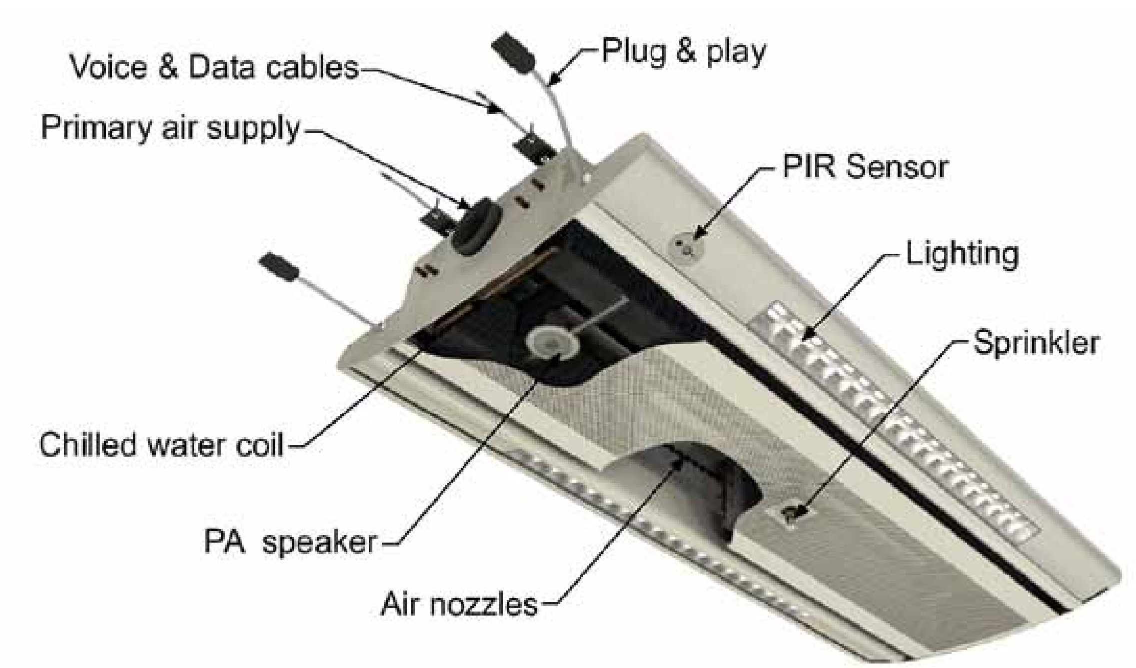


Figure 20: Multi-service chilled beams

MSCBs can integrate both active and passive chilled beams and can be mounted flush with a suspended ceiling or suspended below or directly affixed to the soffit.

The major advantage of MSCBs is the wide range of building services that can be built into the beam in a controlled factory environment (“pre-fabricated off-site”). This leads to a potentially superior build quality compared with on site assembly and installation of different services by different trades. It also offers the facility to factory test services in a more controlled environment. This results in MSCBs normally coming to site with tested services and plug and play connections.

The site delivery can be regulated to site requirements and therefore reduces the total amount of space required for on site storage of the additional services and the beams themselves.

The “plug and play” approach enables rapid installation and services connections with a major saving in on-site time and hence cost saving for the project as a whole.

This type of beam is often of a bespoke design offering the possibility of strong architectural input to develop an MSCB which compliments the building environment.

With this type of beam, soffits can be left exposed, allowing the thermal mass of a building to be used for thermal mass heating and cooling, or Fabric Energy Storage. Leaving the soffit exposed can have particular benefits in refurbishment projects as the design teams can also maximise the floor to ceiling height.

Services typically incorporated into MSCBs can include:

- Luminaires
- Infra-red sensors (PIR)
- Photocells
- Control valves and actuators
- Apertures for sprinkler heads
- Voice and data cabling
- Public address systems

3.11 Cassette chilled beams

Cassette formatted active chilled beams are characterized by modular sized units typically 0.6m x 0.6m and 1.2m x 0.6m. They usually have 4 way outlets providing a potential of higher cooling per linear metre of chilled beam but providing the same room comfort conditions as other active chilled beams.

Care should be taken when positioning four way discharge beams to avoid colliding / converging air steams. Clear space must be left between each chilled beam. Refer to manufacturers for guidance as relative to air volumes and air pressures.

Table 3: Advantages of the different systems

	Radiant chilled ceilings	**Passive chilled beams (95% convection)**	**Radiant/Convective chilled beams (35% radiant)**	**Active chilled beams**	**Multi-service chilled beams (passive/active)**
Comfort	Excellent thermal comfort – very low air movement.	Good levels of thermal comfort if limited to 225W/m.	Excellent thermal comfort very low air movement 300W/m	Good levels of thermal comfort.	See associated cooling type.
Energy Efficiencies	Excellent. Lower running costs than traditional HVAC systems.	Excellent. Lower running costs than traditional HVAC systems.	Excellent. Lower running costs then traditional HVAC systems.	Excellent. Lower running costs than traditional HVAC systems.	Excellent. Lower running costs than traditional HVAC systems.
Architectural flexibility	Full flexibility in visible ceiling design.	Dependent of application – very flexible.	Dependent on application – very flexible.	Dependant of application – very flexible.	Dependant of application – very flexible.
Acoustics	Silent operation. Can incorporate acoustic absorption materials.	Silent operation.	Silent operation. Can incorporate acoustic absorption materials.	Low noise levels-dependent on selection criteria.	See associated cooling type.
Space requirements	Minimal ceiling void requirements. Supply air ducting to separate system.	Dependent on depth of passive beam, and air gap clearance required. Supply air to separate system.	Dependent on width of beam. Supply air to separate system.	Minimal ceiling void requirement for supply air ducting. Soffits can be left exposed.	See associated cooling type. Soffits can be left exposed for exposed thermal mass and reduced running costs.
Building services	Lighting and other ceiling mounted services can be incorporated in the normal way.	Services installed separately.	Lighting and other ceiling mounted services can be incorporated in the normal way.	Services installed separately.	Many building services can be incorporated.
Maintenance	No moving parts – low maintenance requirements, long life expectancy.	No moving parts – low maintenance requirements, long life expectancy.	No moving parts – low maintenance requirements, long life expectancy.	No moving parts – low maintenance requirements, long life expectancy.	No moving parts – low maintenance requirements, long life expectancy.
Heating	No	No	No	Yes	Yes

Performance issues

Many factors play a role in the performance of radiant chilled beams and chilled ceilings. The main considerations are cooling and heating capacity, fresh air supply, air velocity, control, water flow rate, and supply air temperature, volume flow rate and static pressure.

3.12 Cooling capacity

Cooling systems will vary depending on their design and cooling capacities. Specific performance data can be sourced from individual manufacturers. However, care must be taken when comparing the performance figures for different manufactures as outputs depend on the test method. A list of the relevant test standards can be found below.

Once the cooling load for the space has been calculated, the choice between radiant chilled ceilings, passive chilled beams or active chilled beams can be made.

When the particular product has been decided upon, the layout of the chilled ceilings / beams can be prepared. The number and size of terminal units can be calculated, depending on the specified heat loads in an area (e.g. it may be the case that more primary air is provided to active chilled beams with the same pitch or more units are needed on the Southern elevation of a building than the Northern elevation, or additional units are needed in some parts of a building yielding a closer pitch of chilled beams). Individual manufactures can provide guidance in this matter, however special attention should be paid to ensure room comfort conditions comply to BS EN ISO 7730.

There are a number of relevant British and European standards. They are:

- BS EN ISO 7730: *Ergonomics of the thermal environment*
- BS EN 14240: *Ventilation for Buildings – Chilled Ceilings – Testing and Rating*
- BS EN 14518: *Ventilation in Building – Chilled Beams – Testing and Rating of Passive Chilled Beams*
- BS EN 15116: *Ventilation in Buildings – Testing and Rating of Active Chilled Beams*

3.13 Heating capacity

While passive chilled beams and radiant chilled ceilings are normally used in conjunction with a separate heating system, active chilled beams can incorporate a heating section in the coil configuration in the beam.

Guideline performance data is given in the table (*see Page 11*), “Performance and characteristics”.
Note: Whilst it is possible for an active beam to give high levels of heat output this is not adopted because higher temperatures make the air too buoyant and thereby excessive room stratification would occur. To keep stratification to within comfort criteria of BS EN ISO 7730 the water temperature for heating is a mean temperature of only 35°C or a difference between mean water temperature and room temperature of 15K. Specific performance data is available from individual manufacturers.

3.14 Fresh air supply

Typically, passive chilled beams and chilled ceilings work in tandem with separate fresh air supply and extract systems. Such systems deliver conditioned fresh air to the occupied space, reducing humidity levels. Depending on the direction and velocity of the fresh air, it can influence thermal performance. Such performance variations will depend on individual system design.

Active chilled beams incorporate a fresh primary air distribution system, removing the need for additional systems. The air is typically supplied at a temperature of around 15°–18°C. Active chilled beam systems can be designed with variable airflow systems such as Demand Control Ventilation, increasing or decreasing airflow rates to the space depending on load and air quality. However care must be taken to ensure induction of re-circulated room air through the active beam when at low supply air pressures.

Extraction of stale air is still a requirement and will need to be installed independently.

3.15 Air velocity

In the case of active chilled beams, the fresh primary air supplied induces secondary air across the fin and coil system. The greater the primary airflow rate, the higher the induction volume and consequently, the cooling capacity. This can potentially increase the risk of draughts so care needs to be taken when selecting the correct active beam for the project. Individual manufacturers can assist and advise.

3.16 Control
System control is achieved by altering water flow rate and/or temperature in all cases, and supply air temperature and flow rate in the case of active chilled beams.

3.17 Water flow rate
The rate at which water flows through the system will have an impact of the cooling output. The higher the water flow rate, the higher the cooling capacity. Systems can be designed with modulating valves, enabling the rate at which the water flows through the system to be altered (e.g. the water flow rate can be scaled back in winter time compared to summer conditions). However, care needs to be taken that minimum flow rates are adhered to in order to ensure turbulent water flow. Performance can be compromised if this is not taken into account.

3.18 Water flow temperature (free cooling)
The chilled water temperature can be raised in winter-time to achieve the required cooling performance (whilst taking advantage of reduced energy consumption by not having to chill water down to summer flow condition), this is better known in the industry as “free cooling”.

3.19 Supply air temperature and flow rate
Altering the rate at which air is supplied via an active chilled beam is one method of controlling the output, reduce potential over cooling and meet CO_2 requirements in spaces such as meeting rooms. Another is to vary the temperature of the air supplied. Additional cooling can be provided by reducing the temperature at which the conditioned air is introduced to the system. Effects will depend on individual system design and information is available from individual manufacturers.

Specifiers should also consider space dew points to ensure that condensation does not occur. Also that the total air supply to the space can deal with the design range of floor occupation density within the comfort criteria specified.

4 Design

Overview

To ensure that radiant chilled ceiling and chilled beam systems deliver the correct internal environment, it is essential to consider the design of the water and air delivery systems and the associated controls. In this section, we examine the following:

- ***Water distribution and pipe-work***
- ***Ductwork***
- ***Controls***
- ***Condensation prevention***
- ***Ventilation***
- ***Heating with active chilled beams***

4.1 Water distribution and pipe-work

Chilled beam and chilled ceiling systems typically operate at a chilled water inlet temperature of between 14° and 18°C. If active chilled beams are also used for heating as well as cooling, the system has two separate water circuits – the beam heating circuit will have water temperatures of 35° to 40°C whilst the air handling unit's heating coil may have a higher temperature water circuit.

Due to the lower temperature difference between flow water and room air (8–10°C) in a dry cooling system, the water flow rates are higher and the pipe sizes in the distribution pipe-work are larger than in condensing (wet coil) systems. Distribution pipe-work is typically sized to a pressure drop of 50 to 100Pa/m to enable balancing of the pipe-work system using small pressure drops in the balancing valves to avoid noise generation.

Copper, steel, plastic or composite pipes can all be used but should be insulated to save energy consumption. As chilled beams work above dew point there is no need for a vapour barrier in the insulation if the inlet water temperature is kept above the dew point temperature of the room and void.

The main distribution pipe-work should be installed at a higher level than the chilled ceilings/beams to enable the venting of the pipework on the return mains at the highest points (e.g. using automatic venting valves).

4.2 Ductwork requirements

Duct dimensions are relatively small, due to the primary airflow rate being based on fresh air requirements or something slightly higher when compared with much higher air flows associate with all air systems, such as VAV. In traditional active chilled beam systems, the ductwork is a proportionally balanced constant-air-flow distribution system or larger static regain system. If the ductwork is not proportionally balanced then constant-pressure control dampers are utilized. It should be noted that passive chilled beams and chilled ceilings working with a separate supply air systems usually operate with minimum ventilation rates, which equates to the smaller duct dimensions. Likewise some active chilled beams can also operate with minimum ventilation rates creating sufficient induction of secondary air to achieve required waterside cooling

Air pressure control dampers can facilitate demand controlled local zone ventilation, contributing to energy conservation (e.g. in office buildings where various tenants' office hours tend to differ).

4.3 Controls

4.3.1 General

Chilled ceilings, passive chilled beams and to an extent active chilled beams can generally be regarded as self-regulating (i.e. if there is no heat gain present then there is no driver to produce a difference between water flow and return temperature). As heat gain increases this will progressively increase the mean water temperature difference and hence increase cooling capacity.

4.3.2 Control zones

Where the floor plan is large enough to differentiate perimeter and internal zones then separate control zones should be adopted.

Where internal zones have a relatively uniform heat loads it is possible to control as a single zone, or as a series of large control zones.

In perimeter areas, the control zones should be divided to reflect the local façade loads. The perimeter zones should allow for any possible future cellurisation / partitioning requirements.

4.3.3 Control systems

Most proprietary controls suppliers can offer integrated controls packages (Building Management Systems – "BMS") to cover all the requirements of a chilled ceiling or beam system, these variables being:

- Room zone temperature
- Room zone relative humidity
- Outside air temperature
- Chilled water flow and return temperature
- Low temperature hot water supply temperature
- Room occupancy sensor – where demand control ventilation (DCV) used
- Room CO_2 sensor – where DCV used
- AHU supply air temperature
- AHU supply air pressure
- AHU supply air relative humidity
- AHU supply air flow rate
- Chiller set point temperature

If under sill/trench heating is used this can also be included in the overall control system.

4.4 Condensation prevention

Chilled beam and chilled ceiling systems are typically designed to use the dry cooling principle by selecting the ventilation rate, supply air conditions and chilled water flow temperature so that no risk of condensation exists.

Dehumidification of the primary supply air in the air handling unit (AHU) is one of the important factors to prevent humidity levels (RH) exceeding that of the design "dew point" and thus avoiding the risk of condensation.

In order to ensure dehumidification of the supply air during periods of high outdoor temperatures and high RH, the AHU's cooling coil should be sized to not only dehumidify/cool the fresh outdoor air, but also additionally, allow for any internal latent gains.

The supply air humidity ratio should be so low that the ventilation airflow compensates for the internal humidity loads. In practice, the room air dew point temperature is ideally 1°C lower than the flow temperature of chilled water in the ceiling or beam system.

It is recommended that connection pipes and valves be insulated. The following precautionary measures could be implemented in the BMS to avoid condensation:

- Internal RH is monitored to ensure the chilled water flow temperature is controlled above the calculated dew point.
- Condensation sensors can be utilized to shut off the chilled water supply when condensation is detected, this is recommended, especially when windows are open-able to external air.
- In the absence of condensation sensors, open-able windows should be equipped with window switches that trigger chilled water control valves to shut-off.

4.5 Ventilation

Ventilation rates are calculated according to local building regulations or EU standards, particularly *EN 15251: 2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*.

The following table includes an example of ventilation rate calculation based on building material emissions and occupancy loads and is taken from EN 15251:2007.

Table 4: Ventilation rates calculation

Type of Bldg or Space	Category	Floor area m²/person	For Occupancy l/s,m²	Very low polluted bldg l/s,m²		Low polluted bldg l/s,m²		Non-low polluted bldg l/s,m²	
				Bldg	Total	Bldg	Total	Bldg	Total
Single office	I	10	1	0.5	1.5	1	2	2	3
	II	10	0.7	0.3	1	0.7	1.4	1.4	2.1
	III	10	0.4	0.2	0.6	0.4	0.8	0.8	1.2
Landscaped office	I	15	0.7	0.5	1.2	1	1.7	2	2.7
	II	15	0.5	0.3	0.8	0.7	1.2	1.4	1.9
	III	15	0.3	0.2	0.5	0.4	0.7	0.8	1.1
Conference room	I	2	5	0.5	5.5	1	6	2	7
	II	2	3.5	0.3	3.8	0.7	4.2	1.4	4.9
	III	2	2	0.2	2.2	0.4	2.4	0.8	2.8
Auditorium	I	0.75	15	0.5	15.5	1	16	2	17
	II	0.75	10.5	0.3	10.8	0.7	11.2	1.4	11.9
	III	0.75	6	0.2	6.2	0.4	6.4	0.8	6.8
Restaurant	I	1.5	7	0.5	7.5	1	8	2	9
	II	1.5	4.9	0.3	5.2	0.7	5.6	1.4	6.3
	III	1.5	2.8	0.2	3	0.4	3.2	0.8	3.6
Class room	I	2	5	0.5	5.5	1	6	2	7
	II	2	3.5	0.3	3.8	0.7	4.2	1.4	4.9
	III	2	2	0.2	2.2	0.4	2.4	0.8	2.8
Kindergarten	I	2	6	0.5	6.5	1	7	2	8
	II	2	4.2	0.3	4.5	0.7	4.9	1.4	5.6
	III	2	2.4	0.2	2.6	0.4	2.8	0.8	3.2
Dept. store	I	7	2.1	1	3.1	2	4.1	3	5.1
	II	7	1.5	0.7	2.2	1.4	2.9	2.1	3.6
	III	7	0.9	0.4	1.3	0.8	1.7	1.2	2.1

The description of the applicability of categories used in the above table is given below:

I High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements i.e. sick, very young children and elderly persons.

II Normal level of expectation and should be used for new buildings and renovations.

III An acceptable, moderate level of expectation and may be used for existing buildings.

The active chilled beam system's primary airflow rate must satisfy comfort conditions, minimum ventilation requirement and internal humidity level. For passive chilled beams and chilled ceilings the supply air system is independent but must still satisfy the requirements above.

The required ventilation rate in a typical office space is 1.2 to 2.5 l/s,m² (4.3 to 9 m³/h,m²). In order to keep humidity levels within the design parameters, the primary air handling unit must have the facility to dehumidify the supply air (*see section 4.4 Condensation Prevention*).

Active chilled beam systems normally use a constant airflow and operate with a primary supply air temperature reset by the season (in cooling season, 14° to 17°C and in heating season, 18° to 21°C). Lower supply air temperatures can be used if the room system (beam or other heating element) has the capacity also to heat the cold supply air in order to avoid over cooling the room (e.g. in meeting rooms). Also note DCV active chilled beam strategy to offset this issue.

When the specific length of active chilled beams are predetermined, the primary air flow rate to each beam has to be whatever the particular manufacturers chilled beam requires to achieve the cooling performance based on the given design supply air pressure (typically 50 to 150Pa), as well as to ensure effective heat transfer of the cooling coil and to guarantee the operation of the space air distribution. Care should be taken to ensure that the primary airflow rate is not too high in order to avoid excessive induced airflow, which can cause draughts in the occupied zone. The typical airflow rate of an active chilled beam is 4 to 23l/s/m.of beam assuming a two way discharge. **Note:** required air pressure and air flow rate to produce the same amount of waterside cooling can/does vary from different suppliers and as such it is wise to check performance on different manufacturers product literature or selection programmes when making selections.

4.6 Heating with active chilled beams

The design of the heating system begins with defining the required heating capacity. In traditional heating systems, the design is often based on high safety margins when heat losses are calculated. Therefore special care should be taken, as proper chilled beam heating operation cannot be achieved by over-sizing the heating system. In a new office building, 25 to 45W/m² (floor area) of heating capacity is usually adequate.

If the heating water flow temperature of a chilled beam is higher than 40°C or the linear output of the active beam is higher than 140 to 160W/m) in a typical installation, secondary air is often too warm to mix properly with the room air causing a higher level of stratification in the occupied zone. If designed correctly and the suggested maximum inlet temperature/watts per meter heating is designed correctly, then a relatively low temperature gradient in the space occurs; thus maintaining comfortable thermal conditions as well as ensuring the energy efficiency of the system. Increased static pressure onto the active chilled beams also reduces room stratification.

At the perimeter of the building the level of stratification also depends on the window size and glazing inside surface temperature (U value dependant). The higher and colder the window, the colder the air falling down to the floor, and the temperature gradient between secondary air and room air becomes higher. Therefore when, using chilled beams for heating it is recommended that the heat transmission of the windows is moderate (e.g. the inside surface temperature is higher than 12°C and the height is no more than 1.5m).

The heating capacity of active chilled beams is reliant upon the primary airflow being in operation. The temperature gradient between the cold floor and the warm ceiling is slightly mixed by the cold window, but the gradient is still relatively high when the area has been unoccupied for long periods of time (e.g. early morning). Therefore, the ventilation needs to be started early enough to ensure that the warm room air near the ceiling is mixed well before the space is occupied. Sometimes it is necessary to close the warm water circulation of the beam system to increase the mixing of room air during start-up. Early morning air boost can also be used to achieve superior heating in unoccupied zones.

When an office room is occupied, the internal heat sources normally reduce the required heating output and the temperature gradient stays at an acceptable level. However, when calculating the heating capacity of the chilled beam it should be assumed that the air being returned to the heat exchanger is at least 1.5K higher than the design room temperature and that the extract air has a similar gradient.

Proper system operation cannot be achieved by over-sizing the heating capacities. In a modern office building, 25-45W/m² (floor area) is usually sufficient heating capacity. The designer should seek advice from the manufacturer to ensure that the appropriate comfort levels are realised during the heating mode.

5 Selection

Overview

The cooling capacity of a chilled ceiling / chilled beam is a major selection criterion. However, other considerations also play a role in the selection process and these include design, performance, aesthetics, acoustics and cost. The importance of each consideration will vary depending on the particular requirements of each different project. However, some of the main considerations to take into account are:

- ***Design***
- ***Performance***
- ***Occupant activity***
- ***Acoustics***
- ***Cost***
- ***Flexibility***
- ***Access***

5.1 Design

A wide variety of chilled beams and chilled ceilings are currently available, with both off-the-shelf and bespoke variants. The size, shape and colour of products/solutions can be varied to meet specific requirements, as can the paint finish.

In the case of multi-service chilled beams (MSCBs), a wide variety of building services can be incorporated, *see Section 3.10*.

When selecting the possible solutions, attention should be paid to any design constraints for a particular project, such as for example allowable construction depth of the system or required cooling performance on available design parameters. Page 13 has a useful table under the heading “Advantages of different systems”.

5.2 Performance

Chilled ceiling performance characteristics can be found tabulated on page 06. Passive and active chilled beam performance can be found tabulated on page 10.

Note: Levels of chilled ceiling and/or beam performance do vary between different manufacturers, therefore it is advised to check individual manufacturers product literature and compliance to BS EN ISO 7730.

5.3 Occupant activity

The activity of the occupants in the space needs to be considered to ensure good thermal comfort. If the occupants’ work is relatively sedentary, such as in an office environment, the cooling outputs need to be matched to ensure comfort levels are maintained in accordance with EN ISO 7730. In non-sedentary environments cooling outputs can be increased.

5.4 Acoustics

Passive beams and chilled ceilings are quiet in operation although the process of delivering fresh air results in the generation of slight noise in active beams. The noise level depends on a number of factors including its supply air-flow rate and pressure and the frequency and diameter of the nozzles it passes through. The size and frequency of these nozzles on active chilled beams do vary between manufacturers and product literature details the noise levels, air volumes and pressures. These variables can be adjusted to regulate the amount of noise generated and meet specific acoustic requirements.

5.5 Cost

Alongside the initial capital cost of the ventilation, heating and cooling system, whole-life considerations such as on-going maintenance and energy costs must also be considered.

Because of the low maintenance requirements and energy consumption associated with chilled beams and/or chilled ceilings solutions when compared to other systems, the whole life cycle costs for chilled beams and/or chilled ceilings are often lower than other cooling systems.

However, it is recommended that individual project life cycle analysis is undertaken because of the huge variations in building design. Special care should be taken to account for the low maintenance, reduced energy consumption and long life expectancy (30 years+) when undertaking cost comparison with other systems. Other systems may have an initial lower capital expenditure but higher maintenance cost and lower life expectancy. Chilled beams and/or chilled ceilings can be a very cost effective solution, the more years they are in operation the more cost effective they become

5.6 Flexibility

Chilled beam and chilled ceiling systems can be designed to accommodate flexible space planning. Terminal units can be sized and orientated to fit within certain planning grids (e.g. 1.5m increments).

Partitioning can then be added or removed as required. However, this depends on individual system design. Care needs to be taken to ensure the heat loads created by any sub-division or opening-up of a space can be offset by the adjacent chilled units.

As with most systems, there is a trade-off between cost and flexibility. A greater the number of smaller chilled beams provides increased flexibility however, the increase in pipework for passive beams and in addition ductwork for active beams results in greater system costs. Also the unit costs of chilled beams are usually more cost effective the longer the beam length in terms of cost per linear meter.

In the case of active chilled beams at the building perimeter, depending on the space served and the ceiling layout, a choice may have to be made whether the beams are installed parallel to, or at 90° to the façade. Considerations are as above, but also include the potential benefits in terms of thermal comfort when discharging towards the glazing should be taken into account.

5.7 Access

Access to chilled beams and chilled ceilings to the ceiling void for maintenance etc. is an important consideration and individual manufacturers can give detailed information on accessing units. This needs to be considered at the design/ selection stage.

5.7.1. Radiant chilled ceilings

Access to the rear of radiant chilled ceilings is normally via a hinge down mechanism. Panels generally pivot downwards in order for access to the rear of the panel and the ceiling void. Any number of panels can be hinged down at the same time if access to a greater area is required, as each tile has its own cooling element supplied by flexible hoses.

In the case of radiant chilled rafts/sails, the area above the unit is open, with access levels to this space depending on the distance from the soffit. Rafts/sails can be demounted if required.

Alternatively each tile element can be hard connected to avoid the use of flexible hoses. Access is then gained via notional tile runs where mains pipe work is situated. Hard / rigid pipe work connections limit the accessibility options to the ceiling but increase the life expectancy of the system.

5.7.2 Chilled beams

Access to chilled beams depends on a number of factors including their mounting and the design of any casing. Access to chilled beams installed above a suspended ceiling will be determined by the design of the ceiling system. Flush mounted, freely-suspended units or multi-service chilled beams can be accessed in a number of ways including hinge- or drop-down panels.

Chilled beams are selected to satisfy the cooling loads usually with inlet and outlet water temperature differentials, typically ΔT_w = 2–4°C. With energy efficiencies a primary consideration many chilled beam solutions are being investigated to utilise 4-5 degree temperature differentials. This reduces pipework, pumps and value sizes and alo reduces the chiller load. Contact manufacturers for more information.

6 Central plant systems

Overview

Chilled beams and ceilings are part of complete systems, which are designed to provide the optimum indoor climate within the applicable built environment.

Chilled beams and chilled ceilings are the final interface with the occupant, but require other components for them to be able to operate.

In general, there are three main supporting components. These are air handling units, chillers, and pumps. If the system is also providing heating then boilers are also involved.

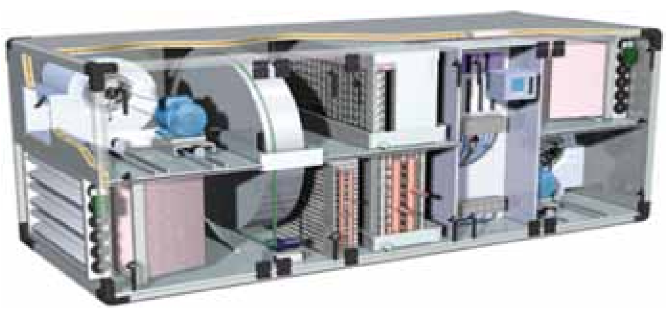


Figure 21: AHU Sections

6.1 Air handling units

Air handling units (AHUs) are a major component within any chilled beam or chilled ceiling system. They deliver conditioned fresh air into the building, either directly to the active chilled beam, or through diffusers for passive chilled beam and chilled ceiling systems.

The role of the AHU is to clean and condition the air as it enters the building and then to distribute it through to the terminal devices. AHUs do this by filtering and then heating and cooling the air depending on the building's requirements. Then the air is 'pumped' through a distribution system (ductwork) by a fan, which is driven by a motor.

The AHU is also where energy recovery devices can be installed to recover any of the energy in the exhaust air and transfer it to the supply air. It is very important that such devices are used as they reduce energy demand dramatically. The introduction of such heat recovery devices such as "Themal Wheel" gains additional SFP (Specific Fan Power) allowances for the system in accordance with Part L of the Building Regulations in England Section 10: Table 37. For example, a thermal wheel of 75 per cent efficiency can reduce heat demand on boilers by up to 95 per cent in England.

AHUs are themselves made up of several components:

Mixing boxes

Dampers are used in mixing boxes to regulate the mixture of fresh air and recirculated air. Normally, with chilled beam and ceiling systems, mixing boxes are not used as the systems tend to have full fresh air AHUs.

Filters

These are usually manufactured from synthetic materials, glass fibre and, in some cases, paper. For chilled beam and ceiling systems fine filter grade F7 (to BS EN 779: 2012) is recommended.

Coils

These are heat exchangers designed to transfer the energy from a medium (usually water) to the air. There are individual coils for heating and cooling.

Cooling coils not only cool down the air, but can also reduce the moisture content in the air (dehumidify). This is important

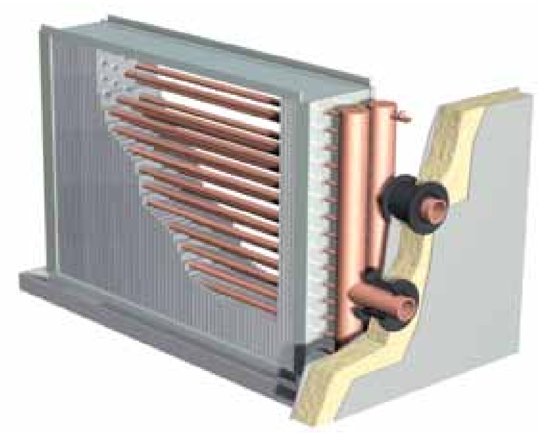


Figure 22: Coil detail

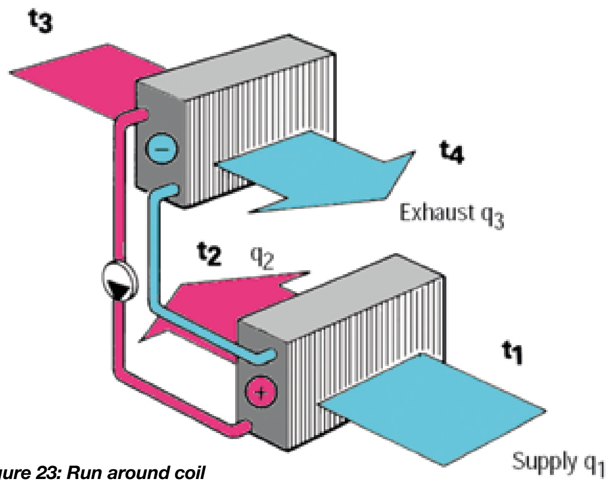


Figure 23: Run around coil

in chilled beam and ceiling applications as, to avoid any issues with condensation problems, the fresh air must have a lower moisture content than the space being served. Therefore, AHU cooling coils are used to dehumidify as well as cool.

Also, it is not necessary for the supply air to be as cold as the temperature coming off the cooling coil, so the air is reheated to a temperature usually in the range 15–20°C. this can be achieved with a heating coil or secondary heat wheel.

In other words, for chilled beam and chilled ceiling applications, there is a requirement for dehumidification and reheat, which means using both cooling and heating coils in summer time for supplying the air at the right condition.

Energy recovery devices

There are many types of energy recovery device, but all of them reduce the energy used to condition and supply the air by a significant amount.

These devices all transfer the energy that is in the exhaust air (air that is leaving the building), into the supply air-flow. Most devices transfer only sensible energy but hygroscopic (enthalpy) rotary heat exchangers can also transfer latent energy in the form of moisture.

There are four main types of energy recovery device used in AHUs.

Run around coil – This is made up of two coils – one in the supply airstream and one in the extract airstream. It is a very simple system and efficiencies tend to be in the region of 40–50 per cent (based on equal flow).

Heat pipes – These are similar to the run around coil but heat pipes use refrigerant as the medium. They have efficiencies of around 50 per cent.

Figure 24: Cross flow plate heat exchange

Plate heat exchangers – As the extract air passes through the plate heat exchanger, it transfers the energy to the aluminium plate and this energy is picked up by the supply air as it passes through. Efficiencies are generally 50–60 per cent.

Thermal wheels – These tend to be the most efficient of all the energy recovery devices. As the extract air passes through the wheel, the energy in the extract air heats or cools down the aluminium. As the wheel rotates, this energy is picked up by the supply air. Efficiencies are between 70 and 80 per cent.

Figure 25: Thermal wheel

Any of the energy recovery devices are suitable for use in chilled beam and chilled ceiling systems.

Fans – The fan ‘pumps’ the air through the air handling unit and the air distribution system. The fan is driven by a motor. With the latest regulations, it is likely that the motor is inverter-driven as this is an energy efficient way of not only starting the motor, but also running it.

Other components can include silencers and humidifiers.

Figure 26: Fans

6.2 Chillers

Figure 27: Chillers

In chilled beam and chilled ceiling systems, the majority of the cooling is water based. For the cooling cycle it is necessary to maintain a chilled water temperature flowing to the system of around 14–16°C. The return temperature is generally 2–4°C higher.

To achieve this consistent water flow temperature a chiller is used.

One advantage of the relatively high chilled water temperatures in chilled beam and ceiling systems is the increased efficiency of the chiller. Due to the lower temperature lift, a dedicated chiller supplying water at 14°C is around 20 per cent more efficient than one having to provide water at 7°C.

Another is that free-cooling can also be used to a greater extent. Free-cooling is where the low outside air temperature for chilling water is used. Because of the higher chilled water temperatures, there is a greater amount of time that free-cooling can be used.

Heat pumps
Air and ground source heat pumps are appropriate for chilled beam systems as they produce both chilled water and hot water at typical flow temperatures which are ideal for chilled beam systems. Due to their nature, these heat pumps operate with much lower energy use than traditional boilers and chillers.

Figure 28: Heat pump

Boilers
Where heating is also provided using the chilled beams, hot water has to be provided and to do this a boiler is required to heat up the water. Due to the nature of chilled beams, it is not necessary to supply the water too hot, normally between 35–40°C.

6.3 Pumps
Pumps are simply devices designed to move fluids or air (a fan is an air pump) from one place to another. They are generally motor-driven and, like the fans, they now more commonly include invertors to minimise the amount of energy used to move the water.

Within a chilled beam/ceiling system the pump's job is to 'pump' the chilled water from the chiller through the system and back to the chiller.

Summary
Chilled beam and chilled ceiling systems are energy efficient, but the savings don't just end with the products themselves. Due to the nature of the systems (for example, using water that is not very hot or cold), the other products in the system, such as heat pumps or chillers and boilers, use much less energy than they would with conventional systems. This, coupled with energy recovery devices in the air handling units and the inverter drives on both fans and pumps, leads to an exceptionally energy efficient system.

7 Installation

Overview

Correct installation of chilled beams and/or chilled ceilings is important to avoid compromising performance levels and ensuring aesthetic requirements are met. Installations should be carried out in accordance with manufacturers' guidelines.

The designer of a chilled ceiling or chilled beam cooling system should be aware of, and take into account, the latest codes and recommendations for pipe-work design. There are, however, a number of areas which need particular consideration, these are set out below.

Water-side connections

7.1 Installation

The main distribution pipe-work should be installed first. Chilled ceilings/beams should then be fixed into the soffit using drop rods, suspension brackets, tray systems or other methods.

The dimensions of the chilled ceiling/beam must be taken into consideration, particularly in relation to the building design and site logistics.

Chilled ceilings/beams are then connected to the main distribution pipe-work using either push fit or compression fittings, flexible hoses, soldering or crimping methods.

It is advisable to leave any protective covering in place until the last possible moment. This will minimise the risk of dirt and dust covering the ceiling/beam and help prevent accidental on-site damage. All coverings should be removed before commissioning.

7.2 Pipe-work design

Determination of the chilled water mass flow rates required and the resultant pipe-work pressure drops need to be established.

7.3 Pipe-work and connections

It is recommended that consideration be given to using either ABS plastic pipe-work or copper, or a combination of the two. This reduces the risk of contamination and future build-up of sludge due to corrosion, which is a danger with black steel pipe.

Connections between chilled ceiling elements and the pipe-work are usually made using suitable flexible hoses, or rigid connections.

7.4 Flow rate

To achieve the design cooling output from the ceiling, it is important to ensure that the required volume flow of chilled water to the chilled beams or chilled ceiling elements is maintained.

7.5 Balancing

Pipe-work serving the chilled elements should be designed to be self-balancing as far as possible. This necessitates the use of reverse return circuits on branches, with pipe sizing to balance pressure drops within practical limits.

Adequate facilities should be included within the pipe-work system design to enable accurate balancing of the water flow rates. It is recommended that these should be as set out in BSRIA Application Guide BG 2/2010 "*The Commissioning of Water Systems*", with purpose-manufactured regulating valves with a built-in measuring facility fitted on the main risers and branches as a minimum.

7.6 Valves

Flow and return connections to chilled beams or chilled ceilings from the main distribution system should be fitted with isolation valves. To achieve the best arrangement of flexible hoses to the chilled panels or beams, the valved connections to the main distribution system should normally be horizontal.

7.7 Contaminants

A chilled ceiling installation contains a large quantity of small bore pipe with many bends. It is therefore important to ensure that the system is as clean as possible to prevent any blockages or reduction in water flow rate due to contaminants.

It is recommended that the pipe-work system is designed to facilitate flushing and cleaning generally in accordance with BSRIA Application Guide BG 2/2010: "*The Commissioning of Water Systems*". Provision should be made for any temporary facilities required. It must be possible to clean and flush the system without the chilled elements in circuit.

7.8 Air vents

It is important to provide adequate air vents at all high points in the pipe-work system to ensure that air can be removed during the initial filling process and during normal running. Air vents should normally consist of a proper air bottle with either manual or automatic relief valve.

7.9 Push-fit flexible hoses

If push-on flexible hoses are used to connect the ceiling elements, then these normally have a rated working pressure of 10bar and a proof pressure of 20bar.This should be considered when establishing working and test pressures. The design should not normally require push-on hoses to be removed once they are fitted.

The hoses used and their application should follow the recommendations in BSRIA Guide 4/2004 "*Flexible Hose Standard – A Standard for Manufacturers"* and BSRIA Code of Practice COP 11/2002 "*Flexible Hoses – Code of Practice for Service Installers"*.

Air-side connections

7.10 Ductwork

Standard industry practice should be followed as described in HVCA DW/144 1998 – *Specification for Sheet Metal Ductwork, Low, Medium and High Pressure/Velocity Air Systems*.

Installation tolerances and dimensions

Consideration of the manufacturing tolerances for chilled elements and chilled beams, as well as their interface with a suspended ceiling, is extremely important. Inadequate attention to this issue can result in aesthetically poor installations or, at worst, high rectification costs may result.

It is therefore imperative that:

1) Tolerances for chilled elements and suspended ceilings (if present) are agreed at an early stage by all interested parties (architect, element supplier, suspended ceiling supplier and installer).
2) Before quantity production of chilled elements and suspended ceilings, it is essential that trial assembly/fitting/interfacing is undertaken including any implications of cut outs in tiles for luminaires, PA speakers etc. These assembly tests should be completed to the satisfaction of, and signed off by, all interested parties.

7.11 Chilled ceilings

Chilled elements are most commonly laid or attached to the concealed or rear face of a metal ceiling tile (*see Figures 1 & 2, page 05*).

A number of important considerations must be taken into account when sizing the elements. These can be summarised as follows:

- The element needs to fit easily into the ceiling tile whose upturned edges may also return inwards, reducing the net available area onto which the element may be fitted.
- Flow and return hose connectors need to be fitted to the elements; the depth of the tile and details of the upturned and return edge will be important in this context.
- The chilled water pipe or waterway pitch and construction of the supporting assembly for the pipes.
- The method of fixing the elements onto the back of the tile.
- Any cut outs and reinforcing associated with luminaires, PA speakers, or other ceiling furniture etc. will create a different element configuration.

Tolerances on the overall dimensions (width x length) of the chilled element are not extremely critical due to the normal clearances used to deal with the issues outlined above. Thus, normal engineering tolerances should be applicable – namely ± 2.5mm.

Chilled ceiling elements can, in some cases, be used as freely hanging exposed standalone systems i.e. convective elements consisting of an array of cooled angled fins above an open latticework ceiling (*see Figure 4*). In this case, normal engineering tolerances of ± 2.5mm would apply to the fin array assembly.

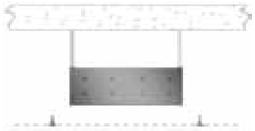
Where chilled elements are used in a plastered ceiling, these are normally fitted to a back plate and then covered with a special plaster skim. However, chilled elements may also be used in conjunction with a plasterboard ceiling and elements may be laid onto or bonded to the rear of sheet plasterboard. A tolerance of ± 2.5mm would apply in both these situations.

Alternatively, chilled elements can be incorporated into plaster tiles, in which case tolerances used for the tile system would also apply to the chilled elements.

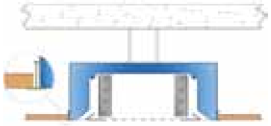
7.12 Chilled beams

These can be exposed without adjacent suspended ceilings or recessed into a suspended ceiling. The normal options can be divided into five categories:

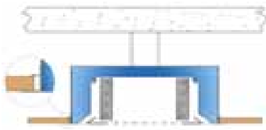
1 Chilled beam above perforated or egg-crate ceiling



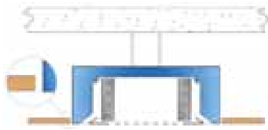
2 Recessed with tee bar ceiling



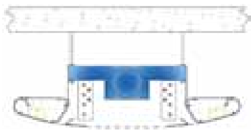
3 Recessed with cover flanges and suspended ceiling



4 Recessed no cover flanges or tee bars, plus suspended ceiling



5 Exposed no suspended ceiling



As with all engineering tolerances, they are function of dimensional size. The following table gives typical tolerances that should be achievable and will harmonise with standards required by Technical Association of Industrial Metal Ceiling Manufacturers – TAIM e.V November 2003 "*Quality Standard for Metal Ceilings and Long Span Metal Planks*" for suspended ceilings.

Table 5: Tolerance table for chilled beams

Chilled beam installation	Chilled beam construction	Overall length		Overall width
		Up to 2m	2m to 4m	Up to 0.6m
Above perforated or egg-crate ceiling	All materials	±2.5mm	±2.5mm	±2.5mm
Recessed with tee bar ceiling	All materials	±2.5mm	±2.5mm	±2.5mm
Recessed with cover flanges and suspended ceiling	All materials	±2.5mm	±2.5mm	±2.5mm
Recessed no cover flanges or tee bars plus suspended ceiling *	All sheet metal	From +0 to -3mm	From +0 to -6mm	From +0 to -4mm
Recessed no cover flanges or tee bars plus suspended ceiling *	Aluminium extruded borders	From +0 to -1.5mm	From +0 to -3mm	From +0 to -2mm
Exposed no suspended ceiling	All materials	±2.5mm	±2.5mm	±2.5mm

* These tolerances are critical and it is essential that agreement is achieved at the design stage.

Overview

Active chilled beams should be connected to a fresh air distribution system, as well as chilled water and L.T.H.W (if heating).

Chilled beams and chilled ceiling panels will need to be connected to a chilled water distribution system.

These air and water systems will also need to be commissioned to ensure that the system as a whole, including the chilled elements, operates at optimum performance, particularly at maximum demand.

To enable successful commissioning, these installations will need to meet certain standards.

8.1 Pipe-work and ductwork

Pipe-work and ductwork will need to be installed to meet specific project requirements.

Ductwork should be tested in accordance with Heating Ventilating Contractors' Association HVCA DW143: 2000 – *Practical Guide to Ductwork Leakage Testing*.

Pipe-work systems will need to be pressure-tested and chemically cleaned in accordance with Building Services Research and Information Association BSRIA BG 29/2011 *Pre-commission Cleaning of Pipework Systems*.

8.2 Water distribution systems

Commissioning of water distribution systems should be carried out to Chartered Institution of Building Services Engineers CIBSE Commissioning Code W: 2010 *Water Distribution Systems*.

8.3 Air distribution systems

Commissioning of air distribution systems should be carried out to CIBSE Commissioning Code A: 1996/2004 *Air Distribution Systems*.

8.4 Commissioning sequence

The general sequence to achieve a successful installation should be as follows:

- Conduct a review of the proposed installation with respect to commissioning issues. Check the water systems to ensure that commissioning valve sets are sized correctly, are of the right type, are correctly positioned and are available in a sufficient quantity to ensure accurate flow measurement. Similarly, check that ductwork sizing is correct for the design airflow rates and sufficient regulating dampers are available and correctly positioned to carry out air balancing (in the case of active chilled beams air control dampers should not be closer than 3 duct diameters or equivalent duct diameters to the inlet of the chilled beam).
- In the water systems, check to ensure correct provision has been made for flushing points, fill points, plant by-pass loops and arrangements for temporary flushing pumps if required. There should also be venting valves installed at the system high points.

- During the installation phase and before pressure testing starts, regularly review the services to ensure that manufacturers' tolerances are adhered to with respect correct positioning of commissioning valve sets, automatic air flow regulators etc (upstream/downstream diameters). Also check that adequate access is available to all system components.
- Chemically clean the chilled water system pipe-work to the guidelines contained within BSRIA BG 29/2011 *Pre-commission Cleaning of Pipework Systems*. During this process, the ceiling elements and the chilled beams should be isolated as they are supplied in a clean state.
- Because of the large amount of small bore primary pipe-work installed into these systems, it may be preferable to use a side stream filtration unit as part of the final flush as these have the capability to remove small suspended particles within the water.
- Upon completion of the final water flush/treatment, ensure a regime is in place to allow for correct fitting of flexible connections to the terminal units to prevent kinking and prevent air from entering the piped system.
- A systematic venting regime should be implemented to ensure that air is removed from the pipe-work.
- The system should then be pre-commissioned to ensure that commissioning can be carried out relatively unhindered.
- Once the air and water system installations have been deemed as complete, the final commissioning exercise will need to start in accordance with CIBSE Commissioning Code W: 2010 *Water Distribution Systems* with additional consideration to any manufacturer's recommendations.
- All control valves that operate specific zone areas, need to be driven to a full flow / demand position to enable the proportional balance to be addressed.
- The final commissioning of the air side systems as indicated above should be carried out in accordance with CIBSE Commissioning Code A: 1996/2004 *Air Distribution Systems*.
- Final performance verification for chilled ceilings / chilled beams cannot be determined unless thermal imaging techniques are adopted on the completed installation.

Note: The correct chilled water flows and the correct flow temperature should be present throughout the system. Thermal imaging can only take place when the surface temperature of the chilled ceiling is significantly lower than the room side surface temperatures of the building fabric.

After carrying out commissioning, a thermal imaging camera can ascertain if there are 'hot spots' that indicate lack of circulation within the system. With the large number of flexible connections that are required for such installations, air locks or kinked connections are possible.

Thermal imaging is the only true means of ensuring correct performance.

9 Service and Maintenance

Overview

This guidance should be read in conjunction with all manufacturers' literature before conducting any work or maintenance on any of the materials supplied for the chilled ceiling or beam installation.

Any work or maintenance in connection with chilled water connections or supplies should only be carried out by the appropriately qualified engineers as designated under M&E connection packages.

All maintenance activities involving ceiling tile removal/ reinstatement should be carried out by competent qualified staff in accordance with health and safety procedures and permits to work systems, as operated by the client.

9.1 Scope of works / description of the systems

The works will generally comprise the following major components:

- Metal ceiling supports including grid, perimeter panels and bulkheads.
- Metal ceiling tiles incorporating chilled elements and acoustic insulation.
- Un-chilled ceiling tiles and/or grilles.
- Chilled beams.
- Fire barriers.
- Acoustic barriers.

9.2 Operational routines

9.2.1 General

The performance and function of the ceiling as a chilled ceiling is determined by the appropriate chilled water supply. Any queries relating to this should be directed to the personnel responsible or the operation/maintenance of the mechanical and electrical systems.

The operational information that needs to be provided with respect to the ceiling installation is how to gain access to the ceiling void through the hinged ceiling tiles, how to disconnect and reconnect the flexible hose connectors to the chilled elements and chilled beams.

Access is required for inspection and servicing of controls mounted within the void. Such access should only be head and shoulders passing above the ceiling plane. None of the ceiling systems are designed to support the weight of a person so no attempt should be made to climb into the void.

Whole areas of the ceiling should only be removed by qualified skilled ceiling fixers. Apart from items stated in this section, no other components should be removed.

9.2.2 Flexible connectors

Any persons carrying out the disconnection/reconnection of the flexible hoses must be fully conversant with the chilled water systems. Refer to the M&E specification and O&M manuals.

Before any disconnection/reconnection of the flexible hoses, ensure that the appropriate isolation valves are closed. Refer to the personnel responsible for the operation/maintenance of the mechanical and electrical systems.

Push fit connectors: The removal of push-on fittings is achieved by using the correct tool as specified by the hose manufacturer. Care should be taken to ensure that any replacement fittings do not compromise the seal and careful inspection of the hose must be carried out as removal may require its replacement. Care must also be taken to avoid any airlocks at reconnection.

Quick-release self-seal connectors: To make a connection, pull back the release collar on the female coupling body and insert the probe, release the collar while completing the insertion and ensure the probe is positively locked. To release pull back the release collar, the coupling will part, ensure the probe is fully removed and the valves in both halves have fully closed. Should there be any significant water egress, the coupling should be reconnected as quickly as possible, and specialist advice sought.

9.3 Maintenance, inspection and water quality

9.3.1 Maintenance

There are no routine maintenance requirements for any of the materials or components supplied and installed as part of the chilled ceiling/chilled beam works, other than cleaning and monitoring of water quality. The cleaning requirements are as detailed in the sections below.

9.3.2 Inspection

There is no inspection regime that needs to be observed in respect of the elements, subject to standards for water quality being strictly observed. Hoses, depending on material selection, will require an inspection in accordance with the manufacturer's recommendations, and in accordance with BSRIA Code of Practice COP 11/2002 "*Flexible Hoses – A Code of Practice for Service Installers*". It is recommended that, as and when tiles are accessed, a general inspection including visual checks should take place to assess the condition of the ceiling components. This should include, but not be limited to, the following:

- General inspection of the ceiling system.
- Inspect condition of safety chains.
- Inspect touch latch mechanisms.
- Inspect hinges.
- Inspect hoses for condition and ensure they are not trapped or kinked.

9.3.3 Water quality

Water quality must be maintained strictly in accordance with the relevant standards and Codes of Practice. Additives must not be corrosive or harmful to elements, couplings or hoses and reference should be made to BSRIA Code of Practice document 11/2002. Any findings should be included in the building maintenance regime.

9.4 Cleaning

9.4.1 Metal ceiling supports including grid, perimeter panels and bulkheads

Cleaning frequency will depend on the function and usage of each area and the efficiency of the air conditioning/heating system. This period can only be determined after handover and occupancy and would be decided by the occupier to maintain a clean appearance. Although the ceiling is usually provided with a durable paint finish, strong chemical detergents should not be used. A mild detergent diluted in warm water, applied with a soft cloth, rinse and finally wiped with a chamois leather or dry soft cloth, will maintain the ceiling in good condition. Oily stubborn stains that are not removed by washing can be wiped with white spirit, but care is necessary to avoid affecting the gloss level of the surface by harsh rubbing.

9.4.2 Metal ceiling tiles incorporating chilled elements and acoustic insulation

These should be treated as those described in 9.4.1.

9.4.3 Chilled beams

The recommended cleaning instructions will be in the manufacturers' guides. However, at 12 monthly intervals, extendable after three problem-free inspections, it is recommended that any dirt, dust etc should be removed from the finned surface of the coil using a soft brush, vacuum line or compressed air line. In the case of compressed air, this must be free from any oil or moisture.In the case of active chilled beams, the above procedures should also be used in connection with any nozzle systems used.

9.4.4 Flexible connectors

There are no maintenance requirements applicable to flexible connectors, but care should be taken to incorporate any manufacturers' instructions into the maintenance schedule, complying with BSRIA BG 4/2004 Flexible Hose Standard.

Overview

The formal process of removing chilled beams and ceilings from active status involves the consideration of a number of factors including:

- ***Drainage***
- ***Refrigerants and electrical equipment***
- ***Recyclability***

10.1 Drainage

Before any repairs or decommissioning can take place, the water contained in part or the whole of the system will need to be drained. In the case of repairs, normal procedures should be followed for re-commissioning of the system.

10.2 Refrigerants and electrical equipment

These products do not contain refrigerants or oil, which unlike other cooling solutions means the associated legislation (F Gas etc) is not applicable and the decommissioning process is therefore easier.

The Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC does not apply either, since these products do not directly contain electrical components. The legislation will, however, still apply to any ancillary products which contain refrigerants, oil or electrical components.

10.3 Recyclability and realising scrap value

All of the metals used in the construction of the chilled ceiling/chilled beam – including steel, aluminium and copper – are recyclable. Rather than pay to dispose of these materials in landfill, it will pay to take advantage of the metals' scrap value.

11 Bibliography

1) ASHRAE standard 55:2010
Thermal environment all conditions for human occupancy

2) BS 8550: 2010 *Guide for the Auditing of Water Quality Sampling*

3) BS EN 14240: 2004 *Ventilation for buildings – Chilled ceilings – Testing and rating*

4) BS EN 14518: 2005 *Ventilation for Buildings – Chilled beams – Testing and rating of passive chilled beams*

5) BS EN 15116:2008 *Ventilation for Buildings – Chilled beams – Testing and rating of active chilled beams*

6) BS EN 15251:2007 *Indoor environmental input parameters for design assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*

7) BS EN 779:2012 *Particulate air filters for general ventilation – Determination of filtration performance*

8) BS EN ISO 7730:2005 *Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort*

9) BSRIA Code of Practice COP 11/2002 *Flexible Hoses – Code of Practice for Service Installers*

10) BSRIA Guide BG 2/2010 *Commissioning Water Systems*

11) BSRIA Guide BG 29/2011 *Pre-commission Cleaning of Pipework Systems*

12) BSRIA Guide BG 4/2004 *Flexible Hose standard – A Standard for manufacturers*

13) CIBSE Commissioning Code A: 1996/2004
Air Distribution systems

14) CIBSE Commissioning Code W: 2010
Water Distribution Systems

15) HVCA DW 144:1998 *Specification for Sheet Metal Ductwork, Low, Medium and High Pressure/Velocity Air Systems*

16) HVCA DW143: 2000 –
Practical Guide to Ductwork Leakage Testing

17) PD CR 1752:1999 *CEN Report Ventilation for buildings – Design criteria for the indoor environment*

18) TAIM e.V (Technical Association of Metal Ceiling Manufacturers) *Quality Standards for Metal Ceilings and Long Span Metal Planks* November 2003

19) *Directive 2002/96/EC*
The Waste Electrical and Electronic Equipment (WEEE)

ANNEX A

Radiant chilled ceiling selection

There are a number of types of radiant chilled ceilings on the market, (*see Section 3 for the most common types*). Ensuring good thermal conductivity between the cooling element and the other parts of the radiant chilled ceilings is important to ensure maximum performance.

The cooling capacity of chilled ceilings is one of the major selection criteria. The technical data of different manufacturers are comparable only if the cooling capacity measurements are made to the same testing standard, BS EN 14240: 2004 *Ventilation for buildings – Chilled ceilings – Testing and rating*.

Care should be taken to ensure the same flow and return water temperatures are being compared. The difference between the mean water temperature and the internal air temperature must also be comparable.

The main considerations when selecting radiant chilled ceilings are as follows:

1) Calculation of heat loads within the design space:
- Selection of thermal environment level.
- Range of room temperatures in the summer.
- Range of room temperatures in the winter.
- Calculation of required cooling capacity.
- Internal and external loads.
- Shading of facades (are passive chilled beams needed at the perimeter to offset the solar gain?)
- Effect of primary ventilation: cooling, humidity and fresh air requirement (separate system).

2) Positioning of radiant chilled ceiling for optimum performance:
- Design for system flexibility.
- Consultation with architect and building services consultant.
- Provision for potential space partitioning changes.

3) Selection of suitable radiant chilled ceilings:
- Determining the amount of ‘active’ chilled ceiling area.
- Integrated lighting or not.
- Selection of the inlet water temperature (cooling) to avoid the risk of condensation.
- Selecting a required temperature differential between the room air and mean cooling water temperature.
- Design primary air conditions in summer and winter.
- Selection of flow and return water temperature differential.
- Calculation of maximum water flow rate.
- Maintaining turbulent water flow conditions.
- Minimum water mass flow rates to maintain turbulent flow conditions.
- System pressure loss calculation.

Does the selected radiant chilled ceiling meet all the design criteria?
- If not -> go back and consider all parameters.
- If yes -> proceed.

ANNEX B

Chilled beam selection

There are many different designs of chilled beams on the market, which makes the selection and comparison between product types and manufacturers difficult. However, there are technical details that can be compared when making a chilled beam selection.

The cooling capacity of chilled beams is one of the major selection criteria. The technical data of different manufacturers are comparable only if the cooling capacity measurements are made to the same testing standard namely BS EN 15116: 2008 *Ventilation for Buildings – Chilled beams – Testing and rating of active chilled beams* and EN 14518: 2005 *Ventilation for Buildings – Chilled beams – Testing and rating of passive chilled beams*.

Data should also be presented with using same parameter values such as primary air flow rate and temperature difference between mean water and room.

It is essential to ensure that the air discharged from chilled beams entering the occupied zone does not have high air velocities that will cause draught and discomfort.

There are four main steps that should be taken into account when selecting chilled beams:

1) Calculation of heat loads within the design space:

- Selection of thermal environment level.
- Range of room temperatures in the summer.
- Range of room temperatures in the winter.
- Calculation of required cooling capacity
- Internal and external loads.
- Shading of facades.
- Cooling effect of primary ventilation.
- Calculation of required heating capacity.
- Calculation of design space heat losses and air leakage.

2) Calculation of supply air volume required by the design space:

- Selection of the indoor air quality level.
- Minimum fresh air requirement.
- Humidity conditions.

3) Positioning of chilled beams for optimum performance:

- Design for system flexibility.
- Consultation with architect and building services consultant.
- Provision for potential space partitioning changes.
- Orientation.

4) Selection of suitable chilled beams:

- Selection of chilled beam type.
- Active or passive chilled beam.
- Active beams parallel or 90° to the façade.
- Integrated lighting and other services or not.
- Selection of the inlet water temperature (cooling) to avoid the risk of condensation.
- Selecting a sufficient temperature differential between the room air and mean cooling water temperature.
- Design primary air conditions in summer and winter.
- Selection of flow and return water temperature differential.
- Cooling.
- Heating.
- Calculation of maximum water flow rate.
- Maintaining turbulent water flow conditions.
- Minimum water mass flow rates to maintain turbulent flow conditions.
- Noise level and system pressure loss calculation.

Does the selected ventilated, cooled beam meet all the design criteria?

- If not -> go back and reselect chilled beam type.
- If yes -> proceed.