## Foreword

This Technical Data Sheet (TDS) should be used in conjunction with the British Standard **BS *EN ISO 7730 Ergonomics of the thermal environment*** *(Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria).*

## Introduction

Thermal comfort is a subjective way to define if the surrounding climate is comfortable or not and a perfect environment can be summarised as:

- The occupant feels thermally neutral and does not wish the environment to be colder or warmer.
- The occupant is not exposed to any local cooling or heating at any place on their body.

The influencing conditions of thermal comfort are as follows (items marked in italics are not covered in this data sheet):

- Activity level
- Clothing
- Room Temperature
- Air velocity
- Turbulence intensity
- *Air humidity in room*
- *Air quality, hygienic*
- *Sound level*
- *Light intensity*

Unfortunately it is impossible to create a thermal indoor climate where everybody is satisfied, since everyone's perception to temperature is different and therefore have different conceptions of what it means to by thermally satisfied; based on practical data it is generally recognised that for a perfect building scenario it is not possible to have less than 5% of occupants dissatisfied.

## The Occupied Zone

When evaluating the indoor environment we only refer to spatial conditions within the "occupied zone" this is the area in which occupants normally reside; referring to ***BS EN 13779 - Ventilation for non-residential buildings*** the occupied zone shall be defined as being 0.5m from any wall and 1.0m from windows, see fig 1.

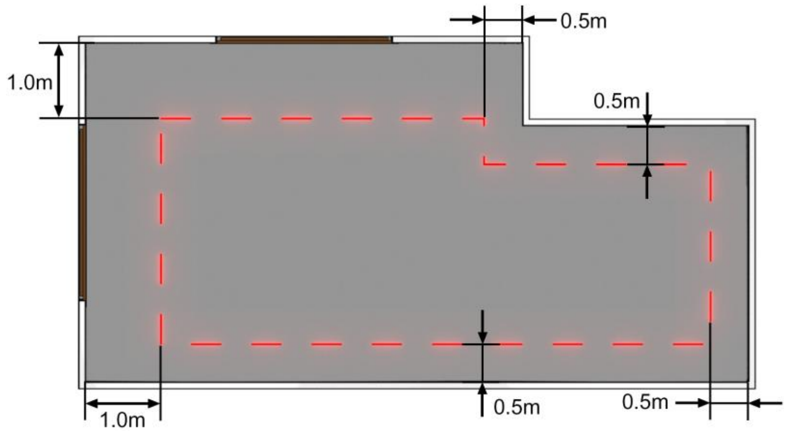


***Fig 1. The occupied zone - Plan View***

It is normal (in office environments) for the occupied zone to be located between 0.1m and 1.1m above fixed floor level (FFL), as at these heights we find the most exposed parts of the seated body, namely the ankles and head/neck, which given the lack of clothing are the most likely locations for feeling any discomfort. In environments where occupants spend most of the time standing (for instance hospital staff working in wards) the occupied zone may be deemed to be between 0.1m and 1.7m above FFL.

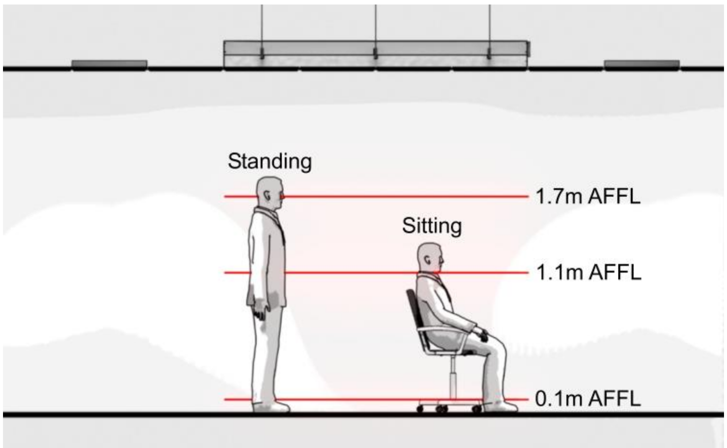


***Fig 2. The occupied zone - standing or sitting.***

**<u>Valuation of Thermal Comfort using BS EN ISO 7730</u>**

In order to have a universal valuation of the thermal indoor climate within the occupied zone we refer to the standard BS EN ISO 7730, which provides methods for predicting the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments by using calculation to determine:

- PMV (predicted mean vote)
- PPD (predicted percentage of dissatisfied)

The PMV predicts the mean value of the thermal votes for a large group of people subjected to the same environmental conditions, but it does not predict how many people are going to feel uncomfortable (PPD).

The PPD determines how many occupants will fall outside the limits of comfort, and thus determines how many people are thermally dissatisfied by feeling too cold or too warm.

In order to determine acceptable levels of PMV and PPD assessment must be made dependant upon the use of the space in question, given that peoples perception of comfort is dependant upon activity levels and the level of insulation (clothing); typical values for normal chilled beam applications (office environments) can be seen in Tables A & B:

**Table A - Metabolic Rates**

| Activity | Metabolic Rate | |
|---|---|---|
| | W/m$^2$ | met |
| Sedentary Activity (Office, Dwelling, School, Laboratory) | 70 | 1,2 |

### Table B - Thermal Insulation of Clothing

| Season | Daily Wear Clothing | Insulation of Clothing ($I_{cl}$) clo | m²· K/w |
|---|---|---|---|
| Summer | Underpants, Shirt with Short Sleeves, Light Trousers, Light Socks, Shoes | 0'50 | 0,080 |
| Winter | Panties, Shirt, Trousers, Jacket, Socks, Shoes | 1,00 | 0,155 |

In addition to the occupant criteria (clothing and activity) the thermal environmental conditions (occupant temperature and mean air velocity) are an integral component in the determination of PMV and PPD; for instance as the room temperature increases the human body can be subjected to higher mean air velocities and still achieve levels of comfort.

In order to provide assessment criteria for different spatial applications BS EN ISO 7730 details the maximum allowable levels of PMV & PPD under 3 separate categories namely A, B & C where A is the highest level of indoor climate; most chilled beam applications (for standard offices) fall under a Category B environment.

The following table details the maximum spatial operative temperatures and mean air velocities dependant upon the desired design category for a typical chilled beam application (1.2 met / 70 W/m2):

### Table C - Typical Design Criteria for Chilled Beam Applications

| Type of Building / Space | Activity W/m² | Category | Operative Temperature (*) °C | | Vertical Air Temperature Difference (**) °C | Maximum Mean Air Velocity (***) m/s | |
|---|---|---|---|---|---|---|---|
| | | | Summer (Cooling Season) | Winter (Heating Season) | | Summer (Cooling Season) | Winter (Heating Season) |
| Single Office<br>Landscape Office<br>Conference Room<br>Auditorium<br>Cafeteria / Restaurant<br>Classroom | 70 | A | 24,5 ± 1,0 | 22,0 ± 1,0 | < 2 | 0,12 | 0,10 |
| | | B | 24,5 ± 1,5 | 22,0 ± 2,0 | < 3 | 0,19 | 0,16 |
| | | C | 24,5 ± 2,5 | 22,0 ± 3,0 | < 4 | 0,24 | 0,21[b] |

** Operative temperature:*
When the air velocity is less than < 0,2 m/s and the difference between the air temperature and mean radiant temperature is less than < 4°C the operative temperature can referred to as the mean value between air temperature and radiant air temperature

$$t_o = \frac{t_a + t_r}{2} \quad [°C],$$

Where: to is the operative temperature [°C], ta is the air temperature [°C] & tr is the mean radiant temperature [°C].

**Between 0.1m and 1.1m above fixed floor level.

***The maximum mean air velocity is based on a turbulence intensity of 40% and air temperature equal to the operative temperature.

Although BS EN ISO 7730 provides relevant maximum environmental conditions for each category it also provides calculations to determine the PMV and PPD based an actual spatial measurement criteria ; the PMV is based on the mean value of votes taken from a large group of persons based on a 7 point thermal sensation scale which can be seen in Table D.

**Table D - PMV thermal scale**

| | |
|---|---|
| + 3 | Hot |
| + 2 | Warm |
| + 1 | Slightly Warm |
| 0 | Neutral |
| - 1 | Slightly Cool |
| - 2 | Cool |
| - 3 | Cold |

The calculated values for PMV and PPD based on the system in question provide an assessment of indoor comfort for the occupants as a whole collective, but does not take into account any localised discomfort which should be assessed under the categories of BS EN ISO 7730 separately.

## Operative Temperature Range & Local Discomfort

Although the comfort criteria regarding PMV and PPD can be assessed (see above), it is also important to determine local discomfort where the operative temperature & draught ratings at all locations within the occupied zone of the space should at all times be within the permissible range as stated for the specific thermal category detailed in BS EN ISO 7730; the range must cover both spatial and temporal variations.

The following table details the maximum percentage dissatisfied for the body as a whole (PPD) within the occupied zone, for example category B details the maximum occupants dissatisfied as a whole at 10%. It is also important to note that for local discomfort the maximum values are just expressed as PD, given not everyone will be subjected to the maximum local discomfort at the same time.

**Table E - Thermal Comfort Categories**

| Category | Thermal state of the body as a whole | | Local Discomfort |
|---|---|---|---|
| | PPD % | PMV | DR % |
| A | < 6 | - 0,2 < PMV < + 0,2 | < 10 |
| B | < 10 | - 0,5 < PMV < + 0,5 | < 20 |
| C | < 15 | - 0,7 < PMV < + 0,7 | < 30 |

To meet comfort criteria for any mechanical cooling device (not just chilled beams) it is therefore important to determine where the highest air movement will be found within the occupied zone. At the location of this highest air movement both air temperatures and air velocities should be assessed because the conditioned air discharge, entering the occupied zone will have a lower temperature than that of the normal / average room condition; as the local air temperature is lower the allowable air velocities will also be lower (see fig 3).

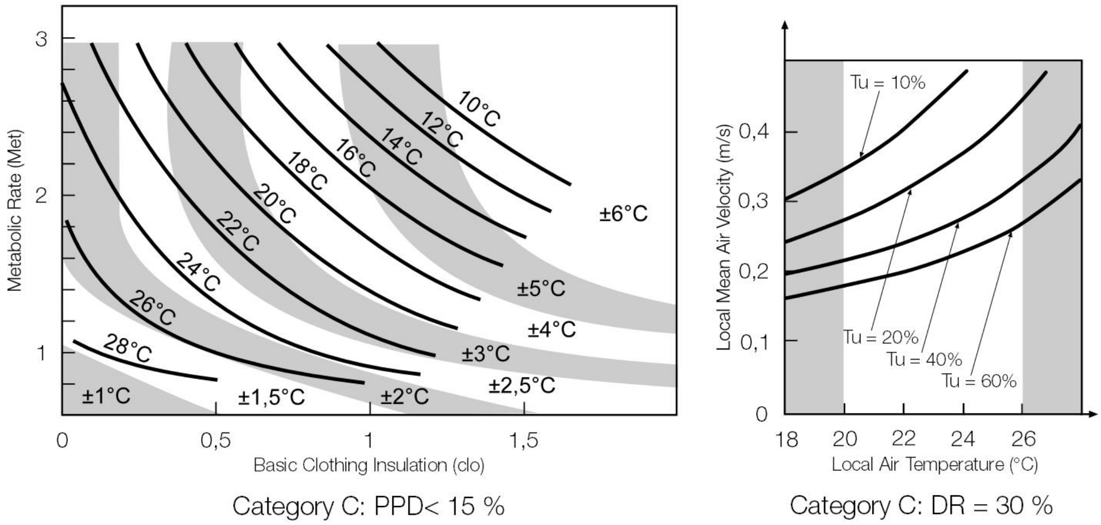


***Fig 3. Optimum operative temperature as a function of clothing and activity & Max. allowable mean air velocity as a function of local air temperature and turbulence intensity.***

As a rule of thumb for chilled beam systems it is normal to assume that for Passive chilled beams the maximum local air velocity will be found directly below the cooling element at the centre of the beam given that the unit is driven by natural convection; an example of this can bee seen below in figure 4 (note the highest location of air movement is indicated by red arrows).

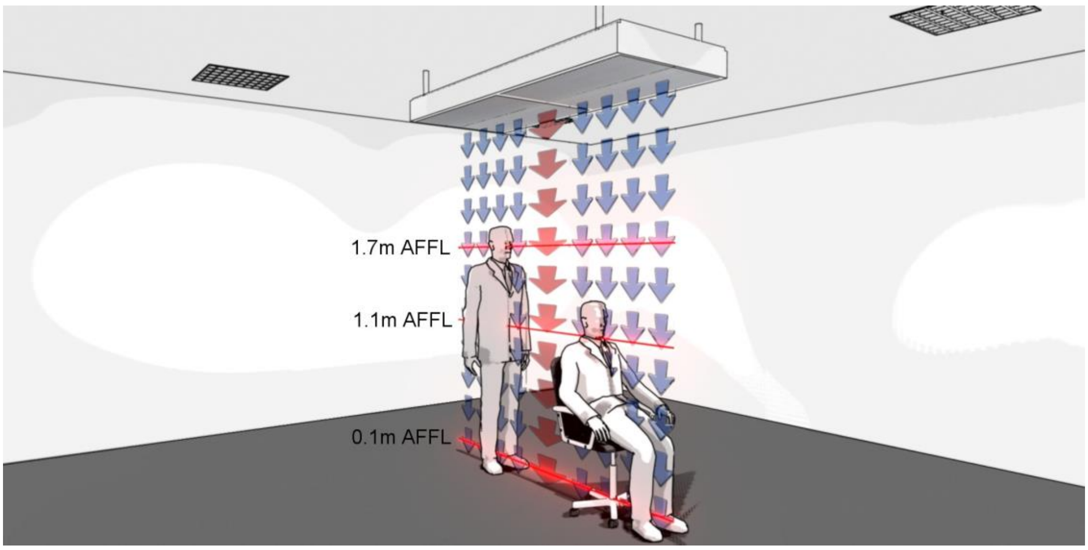


***Fig 4. Typical Passive Chilled Beam System***

With active chilled beams it is more difficult to determine where the highest air velocities will be found given they utilise fresh conditioned air at pressure supplied by a central air handling unit (AHU) to develop induction, this in turn allows the conditioned air discharge direction to be controlled usually by utilising the Coander effect. In general most active chilled beams ensure the conditioned air is delivered horizontally and entrains the ceiling; in these instances the highest air velocities are normally found directly between two adjacent beams where the horizontal air streams collide see figure 5.

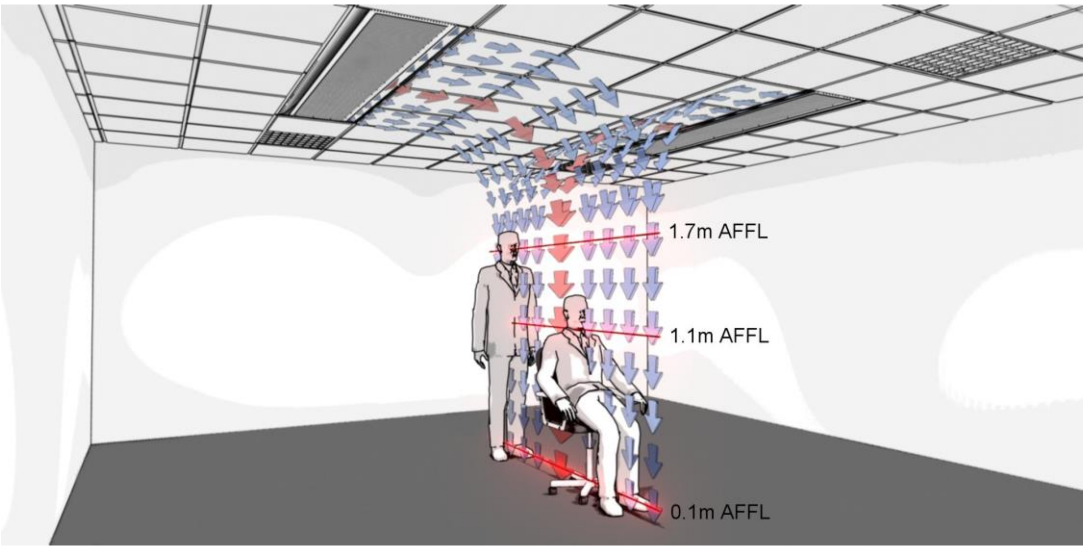


***Fig 5. Typical Active Chilled Beam System with Converging Air Streams***

In situations where the air discharge from the active beam has not entrained sufficiently or the active beams are positioned apart at a sufficient distance so that the air streams do not collide, the highest air velocities and will be found somewhere between the beams, in this instance it will be necessary to complete an air measurement traverse perpendicular to the centre of the beams see figure 5.

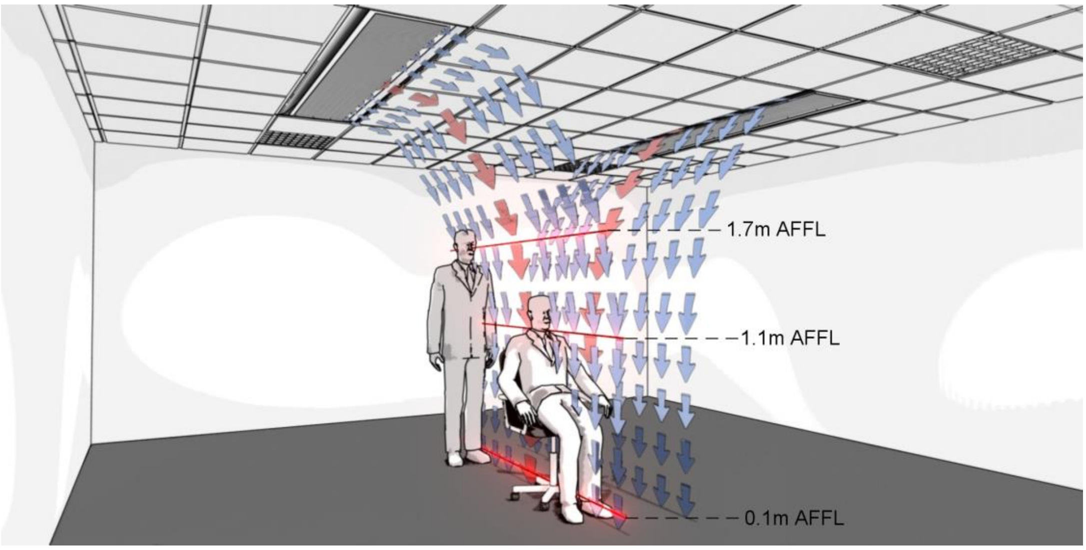


***Fig 6. Typical Active Chilled Beam System with Non-Converging Air Streams***

As the air discharge profile is dependant upon the individual products construction the location of maximum local air velocity may vary; therefore it is always best practice to either complete a measurement traverse both along the product and across the air streams and / or use hand held smoke to provide a visual aid in determine where the local air temperature and velocity measurements should be taken.

In order to determine the PPD due to draught (DR) it is necessary to determine the turbulence intensity (Tu) at the location of the highest air movement; turbulence intensity (Tu) is a figure which represents how constant the air movement is and its range. The turbulence intensity has a direct relationship with comfort, given that if we are subjected to something which is very constant it provides much less annoyance and higher comfort than something which is constantly changing.

To measure the turbulence intensity a significant quantity of air velocity readings should be taken to determine the maximum mean air velocity and it's standard deviation, at the same time air temperature readings should be taken at the same location to determine the local air temperature. The measured results can then be applied to the relationships detailed in BS EN ISO 7730 to determine draught rating (DR) compliance with the desired spatial category (A, B or C).

## Chilled Beam Performance Criteria

Given that the air movement is dependent upon the product and scenario in question there are always some exceptions regarding what criteria will achieve acceptable levels of comfort, albeit the following table taken from the CBCA Guide - *An Introduction to Chilled Beams and Ceilings* figures that have generally been agreed as "good practice" in achieving a category B environment:

**Table F - Typical Chilled Beam Design Criteria to achieve BS EN ISO 7730 Category B**

| **Characteristic** | **Passive 95% Convection** | **Passive 65% Convection, 35% Radiant Absorption** | **Closed Active** (2 Way Air Discharge) | **Open Active** (2 Way Air Discharge) |
|---|---|---|---|---|
| Potential Cooling Capacity | ≤ 225 w/m | ≤ 300 w/m | ≤ 500 w/m | ≤ 550 w/m |
| Air Volume | N/A | N/A | ≤ 23 l/s/m | ≤ 23 l/s/m |

Note the above table is based on the following:
Mean water temperature = 16 °C, Water flow to return difference = 2 dTK,
Average room temperature = 24 °C
Average room temperature to mean water temperature difference = 8 dTK
Chilled beam pitch = 3m