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Improving comfort and energy efficiency with ceiling cassettes

Physical comfort in the workplace has been shown to increase workers' productivity and can be achieved with the aid of well-designed air-conditioning systems – such as ceiling cassette fan coil units – which also improve energy efficiency. It is sponsored by Daikin Airconditioning UK.

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There is a continual striving for better comfort conditions in the workplace and, at the same time, a need to reduce the energy consumption required to achieve that level of comfort.

This article considers the complex issues surrounding comfort and some developments that have taken place to improve comfort and efficiency when using ceiling cassettes for air conditioning.

Introduction to comfort

A broad definition of comfort is "that condition of mind that expresses satisfaction with the thermal environment" [1]. There will always be dissatisfaction expressed by some and the design process must include features that will reduce this to a minimum. There are many factors that influence comfort:

- thermal conditions
- visual elements
- acoustic elements
- electromagnetic and static electricity
- air quality.

Here we shall confine ourselves to thermal comfort, which will include:

- temperature
- humidity
- air movement
- air quality.

In addition to these environmental factors, there are also personal conditions that affect our feeling of comfort:

- clothing
- activity level.

Again, we shall restrict the article to temperature, humidity and air movement, but further reading suggestions are given should you wish to explore this topic further.

For temperature, it is usual to refer to the operative temperature, which combines the room air and radiant temperatures. Table 1 is a subjective scale of feeling hot or cold. A change of 3K will alter the thermal sensation by about one unit. For example, raising the temperature by 3K for a person working at a desk and feeling "slightly warm", will make them feel "warm". Information on suitable temperatures for various applications can be found in the CIBSE Guide A 2006.

Air movement in a space has a cooling effect on the occupants. If the air speed is too high, complaints may be made about draughts. If the air speed is too low, complaints about air quality arise. The generally accepted range of air velocity in an occupied area is between 0.1 and 0.3 m/s, although higher velocities can be used in naturally ventilated spaces in the summer, to provide a cooling effect. Studies also show that varying the direction of air flow makes occupants more tolerant of air movement. For ceiling air discharge, such as cassettes or ducted diffusers, it is important that at the occupied height in the room, the supply air temperature and speed has mixed with the room air to produce the comfort level required. Figure 1 shows the percentage of people dissatisfied as a function of mean air velocity.

Humidity has little effect on the warmth feeling and for most applications humidity in the range of 40-70% is acceptable. However, humidity levels are important in the areas of mould growth, storage of artefacts and static electricity. Figure 2 shows acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing, as recommended by ASHRAE [2].

Measurement of thermal comfort is complex, but the PMV/PPD method does provide an assessment of comfort. It is a mathematical model, based on work done by Fanger [3], of human thermal physiology calibrated against the warmth factor shown in Table 1.

PMV is the "predicted mean vote" and combines the effects of air and radiant temperatures, air movement and humidity with clothing and activity level, to produce the thermal sensation scale of Table 1. It is the mean value of the votes of a large group of people doing the same thing, in the same environment, dressed the same.

PPD is the "predicted percentage dissatisfied" and identifies the percentage of people who would be dissatisfied with their thermal comfort at particular conditions. Figure 3 shows the relationship between PMV and PPD, where an example of a PMV of –0.5 (+1 is slightly warm and -1 is slightly cool) relates to a PPD of 10%, ie, around 10% of the people will be dissatisfied. Note that when PMV is 0, ie, the neutral point of the thermal sensation scale, 5% are still dissatisfied.

Table 1 Thermal sensation scale [1]

Index value	Thermal sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

Ceiling cassettes

Many of the factors described in the introduction affect the levels of personal comfort and energy efficiency achieved via modern air-conditioning ceiling cassette fan coil units. Airflow distribution patterns, the elimination of cold draughts, temperature differentials, operating sound, dead zones, air velocity, unit controllability, performance flexibility and unit location, etc, all have a major influence on the provision of the optimum indoor climate. However, it is fair to say that while many cassette units on the market perform reasonably satisfactorily,

Figure 1 Percentage of people dissatisfied as a function of mean air velocity

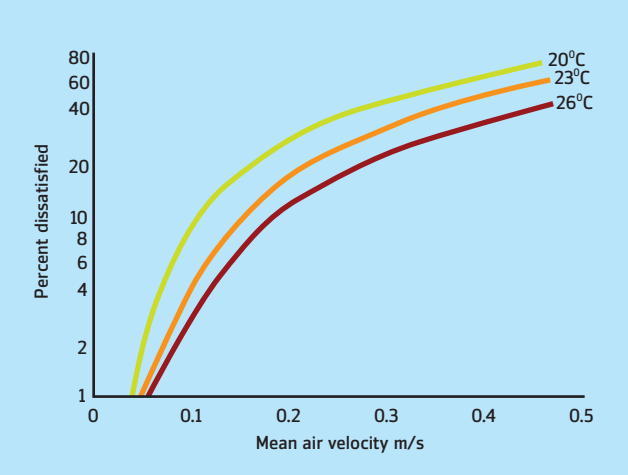


Figure 2 ASHRAE summer and winter comfort zones

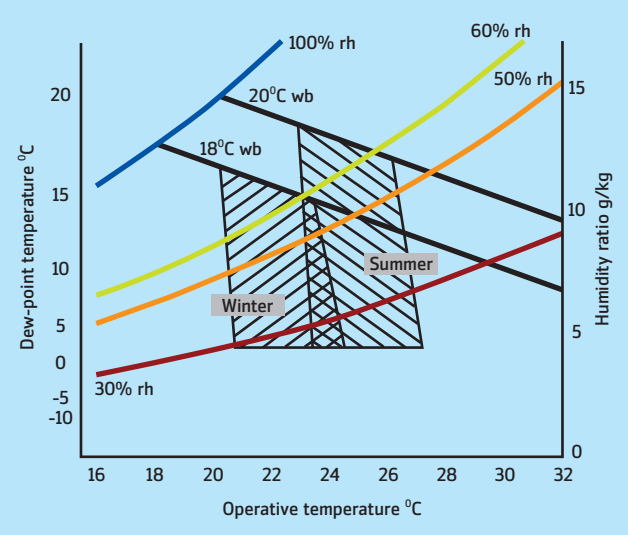
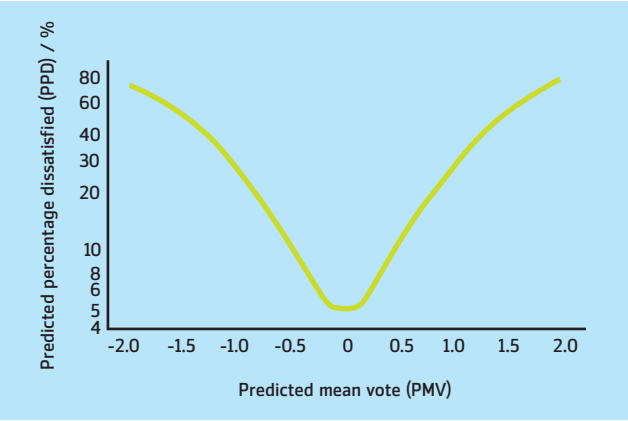


Figure 3 PPD as a function of PMV



system designers are regularly faced with specifying units that lack the ability to address many of these factors.

Developments in ceiling cassettes have arrived at an innovative solution – at present unique – of a Class A energy-rated ceiling cassette that provides 360° radial air discharge with the attendant benefits of uniform airflow, reduced temperature differentials, less draughts and improved energy efficiency. The cassette is designed for use in all forms of commercial office, retail, restaurant and hotel applications.

The cassettes can be used with VRV/VRF systems in a cooling capacity range from 2-14 kW. An important factor with ceiling cassettes is their depth, ideally as small as possible to reduce the required false ceiling height. A development here offers a "thin" body cassette of 214 mm depth. Operating sound is at the remarkably low level of 27 dBA or comparable to the sound of rustling leaves.

Improved comfort conditions in the room are achieved by the 360°, all-round air distribution, made possible at the casing corners by repositioning the float switch and drain pan. Most current four-way blow ceiling cassettes have inherent dead zones in their airflow patterns. Figure 4 illustrates the improvement in the comfort index throughout the conditioned space. The cassette's uniform airflow discharge produces a more uniform temperature distribution and the colour distribution indicates the variation in PMV index. The neutral zone is –0.5, and results show that the PMV index has improved from 78% to 87%.

During the cooling cycle, the airflow pattern of a standard four-way blow cassette tends to give rise to a lower temperature in less occupied areas of a room and higher temperatures near windows. The reverse situation occurs during the heating cycle. The new cassette's uniform temperature distribution overcomes this problem and in doing so reduces the airflow velocity from the 1.65 m/s of a standard four-way blow cassette to 1.24 m/s with a consequent 25% reduction in cold draughts during the cooling cycle, plus an energy reduction from the fan.

Energy efficiency also stems from uniform airflow and temperature since the unit's reduced temperature differentials minimise unit operating cycles and enable a higher cooling temperature setting with an attendant 15% saving in energy consumption. As an option to the thin-bodied cassette, it is possible to use the high COP cassette, which incorporates a larger surface area heat exchanger, increases COP and reduces energy consumption.

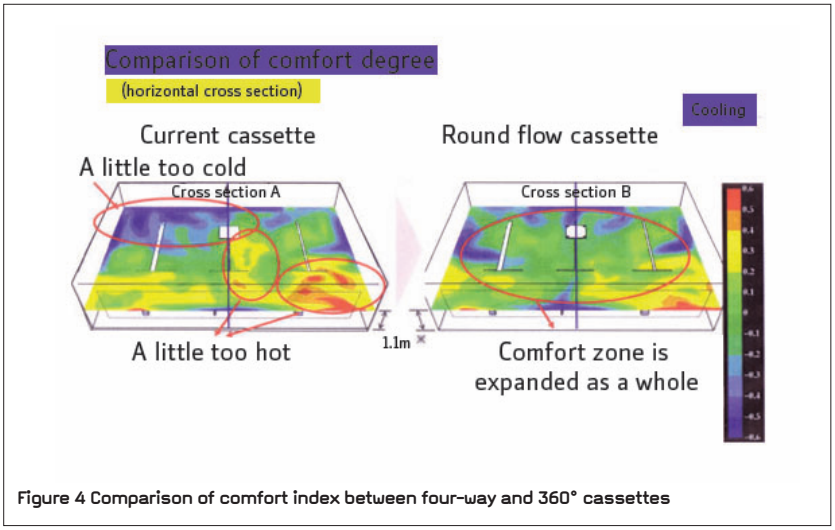


Figure 4 Comparison of comfort index between four-way and 360° cassettes

The development of this cassette includes the flexible use of 23 different airflow patterns. As well as the 360° all-round air flow, the use of closure kits to shut off relevant louvres enables four-way, three-way and two-way flow patterns to be achieved. This flexibility enables the unit to be installed in corners or small rooms. During four-way flow, the air volume is slightly decreased when the corners are closed off and in three-way and two-way flow, the air is deflected slightly downwards.

Further developments in the control of the cooling and heating include the incorporation of a humidity sensor. The cassette control is from the centralised control network which enables direct connection to its I-Controller, I-Manager, Lon Gateway and BACnet Gateway systems. The remote controller offers easy finger tip control and is fitted with a schedule timer allowing the air conditioning to be programmed on a daily or weekly basis. An optional remote on/off controller enables the system to be started or stopped from a mobile phone via a field supplied telephone remote control. The optional "forced off" condition enables the unit to be switched off automatically when, for example, a window is opened.

The VRV outdoor unit is based around integrated inverter control and therefore matches output to cooling or heating demand instead of supplying maximum load purely on the on/off basis of non-inverter systems. Furthermore, the inverter contributes to added comfort by reducing the lead time necessary to reach the required indoor temperature. Once the temperature is reached, the inverter continuously scans the conditioned area for small changes in temperature and adjusts the temperature in seconds in order to maintain occupant comfort.

Practical developments that assist in easier installation and maintenance procedures have also been made. The cassette's weight ranges upward from 19 kg. Lightweight hollow-bladed turbo fans also contribute to the weight reduction. Easier drain-pan maintenance can be achieved without removal of the decorative panel and condensate draining can also be viewed via the clearly visible drain socket.

An integral "home leave" facility can be activated when the occupant leaves the room for a lengthy period of time, such as a holiday. On activation, the room temperature is automatically set to a minimum of 10°C, at which point all connected indoor units will switch to heating mode. The function ceases to operate when the room temperature reaches 15°C and should also be switched off when the occupant returns home. ■

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References

[1] ASHRAE Standard 55 1992

[2] ASHRAE Handbook – Fundamentals, 8-12, 2005

[3] BS EN ISO 7730, 1995, Moderate Thermal Environments. Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort

Further reading

- **CIBSE Guide A 2006**
- **CIBSE Knowledge Series – Comfort 2006**
- **Daikin Roundflow Cassette literature**