New solutions for air diffusion

by Alan Lyall

The choice of an air diffusion device depends very much on the nature of the project, as different products perform in different ways. This article addresses the overall design requirements of ceiling-mounted air diffusion equipment, and explains their air flow characteristics.

Air diffusion is under the spotlight: system design continues to expose the deficiencies of conventional equipment, while building owners and occupiers are becoming more critical of poor environmental conditions.

The demands of product design arise from a variety of requirements including aesthetics, thermal comfort, energy usage and layout. It is clear that a wide range of solutions is necessary to satisfy the demands of the modern internal environment.

Technical practicalities

The air movement within the occupied zone of an air conditioned space, supplied from ceiling mounted diffusers is influenced by:

☐ outlet velocity and flow rate – "inertial forces" which determine the overall flow patterns;
☐ supply to room temperature differential and flow rate – "buoyancy forces" which if significant, will modify the inertially driven patterns;
☐ outlet type – geometry of diffusers including jet shape and size, jet direction, influence of surfaces around the outlet and jet turbulence;
☐ spatial arrangement – room geometry including room height and separation of outlets.

The room shape, and to a large extent the layout of diffusers, is decided from factors other than air diffusion design. Similarly, the air flow rates and temperature differentials are calculated from known heat loadings. Diffuser geometry must therefore be varied to suit each type of project and diffuser design must provide sufficient scope for application flexibility.

Optimising diffuser design

An ideal supply air outlet would be tolerant of temperature differentials, thus allowing the system designer a relatively free hand to extend the performance of other system components. For example, the use of low temperature supply air systems has created a market for high induction outlets, previously reserved for special projects. The advantages of smaller flow rates, ducts and plant are obvious and diffuser manufacturers have recognised this fact.

In the same way, an ideal diffuser should be tolerant of varying air flow rates. The benefits of vav supply can only be optimised if air flow rates to multiple zones can be reduced to a minimum, thus avoiding the need for reheat.

Many outlets function over a range of flow rates by diffusing air across the ceiling surface using the coanda effect. The range of outlets which use the coanda effect has been increased by use of 'swirl' pattern designs which twist the air as it leaves the diffuser. This results in increased turbulence and mixing, shortens the throw and produces a more stable jet.

The principles of throw reduction can be taken to the limit by:

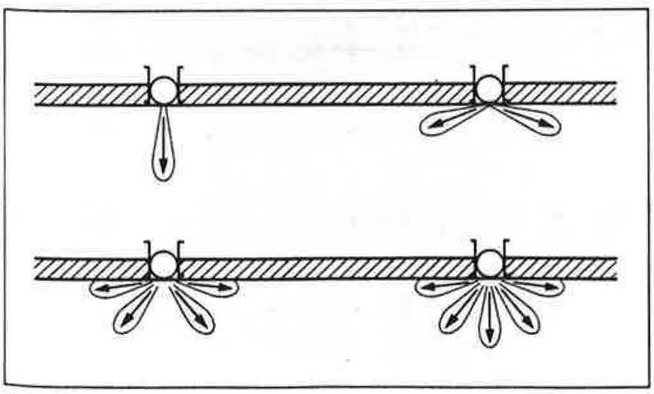
☐ reduction of the outlet size so as to create a series of microjets;
☐ eliminating the coanda effect so that the jet envelope area is greatly increased, thus allowing entrainment to be maximised;
☐ creating turbulence – with stable rotational effects.

Conventional linear diffusers generally use one or more continuous slots. This allows limited jet adjustment due to the coanda effect where:

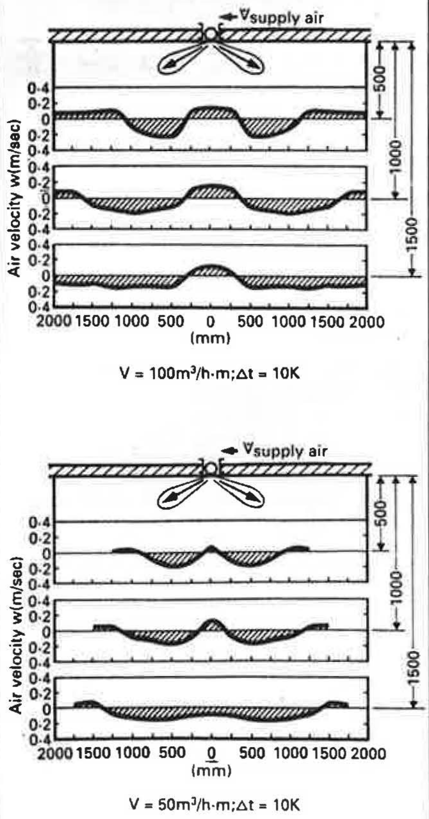
☐ jet angles of 45-90° are possible;
☐ jet angles less than 45° are impossible or unstable due to the coanda effect.

By using a series of alternating microjets it is possible to obtain jet angles less than 45°, because induced air is allowed to flow into the negative pressure areas near the ceiling.

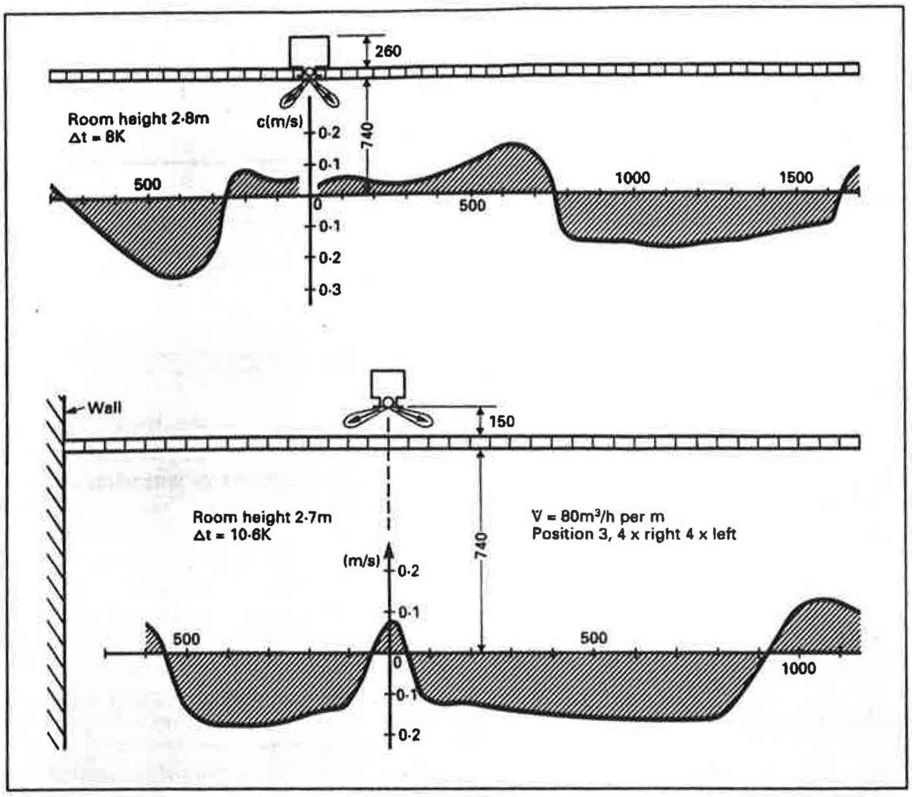
In addition, the small, discrete jets result in a faster velocity decay because of the efficient mixing provided by increased jet surface area. Microjet diffusers incorporate all the features necessary to deliver high air change rates at high cooling differentials, that is:



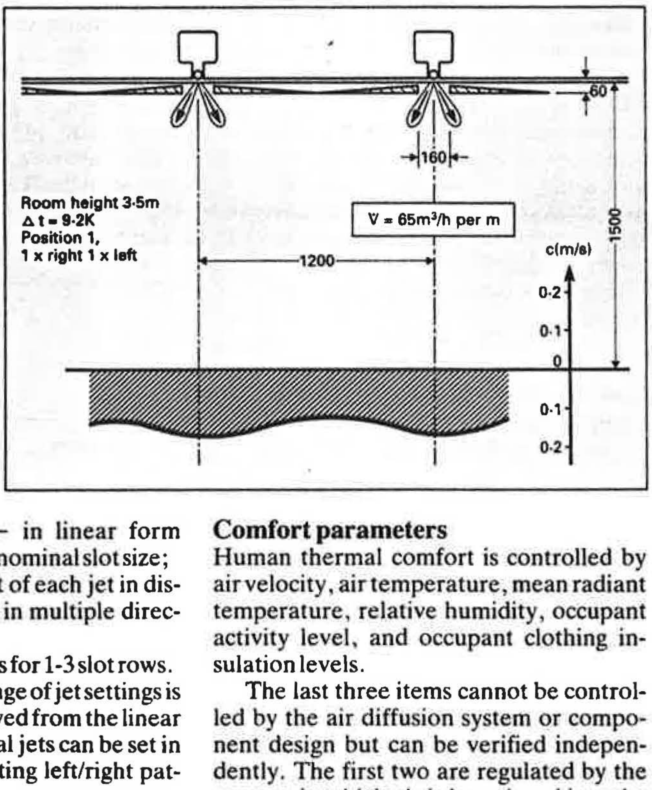
Left, figure 1: Range of flow patterns possible with microjet diffusers.



Right, figure 2: Effect of variable air flow rates on the performance of microjet diffusers.



Above, figure 3: Example of diffuser fitted with an open cell ceiling.



Right, figure 4: Example of diffuser fitted within a recessed suspended panel ceiling.

☐ optimised jet size – in linear form 60 mm long for a 20 mm nominal slot size;
☐ individual adjustment of each jet in discrete steps to spread air in multiple directions;
☐ modular constructions for 1-3 slot rows.

An example of the range of jet settings is shown in figure 1, as viewed from the linear axis of the slot. Individual jets can be set in discrete steps of alternating left/right pattern.

Considerable research has been carried out in both laboratory and application tests to verify the fundamental performance of microjet outlets[1]. Test results show that an initial outlet temperature differential of 14°C is reduced to 0·4-0·6°C at head level, with a 2·8 m ceiling height.

The high induction outlet mixes room air so efficiently that a stable, downflow pattern is produced with:
☐ air speeds less than 0·2 m/s at head level;
☐ jet downflow area of over 2 m in the plane of the jet;
☐ 96% temperature decay at head level.

Comfort parameters

Human thermal comfort is controlled by air velocity, air temperature, mean radiant temperature, relative humidity, occupant activity level, and occupant clothing insulation levels.

The last three items cannot be controlled by the air diffusion system or component design but can be verified independently. The first two are regulated by the manner in which air is introduced into the occupied space. Guidance on the selection of comfort parameters is clearly outlined in *ISO 7730*[2] and discussed by Olesen[3].

A downflow pattern of air diffusion results in a temperature gradient producing "cool head, warm feet". This is generally accepted to provide a fresh, comfortable environment. Rotational, mixing patterns produced by conventional diffusers result in a less acceptable temperature gradient of "cold feet, warm head" within the occupied zone.

These systems also usually result in wider variations in air movement across the working plane. Areas of near stagnation occur at the centre of rotation which is generally at the upper levels of the occupied zone. Areas of higher average air velocity occur where the jet finally penetrates into the occupied zone at head level or perimeter floor level.

The downflow arrangement from microjet outlets produces wide bands of stable, slow moving air which are in relative terms less sensitive to air flow and supply temperature variations.

It is possible to design air distribution systems for cooling differentials of 14°C, allowing reduced plant size and ductwork and chiller loading design/energy savings.

The microjet principle also ensures jet flow stability over a wider turndown range – typically 100-20%, thereby maximising energy use (avoiding terminal reheat) as shown in figure 2.

The downflow pattern is however not suitable for all air heating systems with supply/room temperature differentials over 5°C. If perimeter heating of this type is required it is recommended that it is achieved with separate under-glazing heaters or separate reheat slots designed to deliver air to floor level during warm-up periods.

Microjet diffusers are suitable for many applications where conventional diffusers are problematic:
☐ architectural ceilings which are composed of open grids or coffers, which do not allow easy integration of horizontal diffusion systems. In these cases the downflow pattern can be applied with relatively few problems (figure 3);
☐ microjet diffusers can be recessed into ceiling elements so as to remove the product from the visual field (figure 4);
☐ downflow distribution can be used under cooling loads with ceiling heights over 3 m;
☐ performance of exhaust air luminaires are not compromised by short circuiting of the supply jet attached to the ceiling;
☐ adjustable microjet diffusers are ideal where obstructions, such as beams and uplighters cause jet deflection.

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References

[1]Dr-Ing W Honmann, "The New LTG Diffuser". *LDB LTG Technical Report No 21, 1977*
[2]*ISO 7730:1984 Moderate Thermal Environments*
[3]B W Olesen, "Local Thermal Discomfort", *Bruel & Kjaer Technical Review No 1, 1985*