4112

Engineering the air

Control of room air movement is essential to ensure the removal of contaminants and retain good indoor air quality. Paul Appleby here offers some ways to give up passive smoking

Most air conditioning and ventilation systems rely on the principle of dilution to create heat exchange and contaminant control. Hence, in theory, contaminants which enter the building diffuse uniformly through each room. However occupants close to the source may inhale much higher concentrations than the mean. A well known example of this is passive smoking. A concentrated and cohesive plume of tobacco smoke may be released from a smoldering cigarette or exhaled by a smoker, and enter the facial region of a nearby occupant, causing discomfort and possibly irritation of the eyes and respiratory system.

This is a similar problem to contaminant control in factories. Some engineering approaches to limiting exposure to airborne contaminants in non-industrial applications have mainly been adapted from industrial ventilation design and can prove successful.

Displacement ventilation

The term "displacement ventilation" is normally applied to mechanical ventilation or air conditioning systems which supply air through low velocity air terminal devices located close to the floor. These devices generate very little momentum, and air flow patterns in the room are driven primarily by convection.

If contaminants evolve close to the warm surface in the room and, if conditions are favourable, most should be carried into the upper region of the room by the convective plumes. However, if they evolve from a source located below the occupants' breathing zone, exposure is more likely. The degree of exposure depends on whether the contaminant can be entrained by the plume, the strength of the convective forces, the position of the source in relation to the occupants, and whether disturbances such as crossdrafts can destabilise the plume. Furthermore if there is insufficient supply air to "feed" the plume, the contaminants within it stratify below the breathing zone. There is also a risk that stratified contaminants might be carried downwards into the occupied zone if they are cooled by coming into contact with a cold surface. This effect can be limited by ensuring that all surfaces above the occupied zone are kept as warm as possible. Windows should be sealed and have their surfaces warmed during winter by convection currents rising from heaters. Roofs should be well insulated and heated if necessary.

Personal air supply

Another way of introducing air at low level is via an outlet close to each seated occupant. The air may be supplied as a rapidly diffusing jet, either through a fixed grille or an outlet which is adjustable for direction and, with some types, equipped with means for adjusting spread. When used in aircraft, cars etc, these devices are normally adjustable for flow rate and can be shut off. If this facility is provided in buildings a variable volume air distribution system is required.

This system is sometimes called the microclimate system because it provides local control of the airflow patterns around each individual. It has been used with some success in fixed-seat auditoria and, combined with floor outlets, in offices with raised floors.

Although there will be some transfer of airborne contaminants between neighbouring microclimates, most, including environmental tobacco smoke, should be entrained by the supply jet, and carried into the upper zone of the room, assisted by convection currents. As with 39 ▶

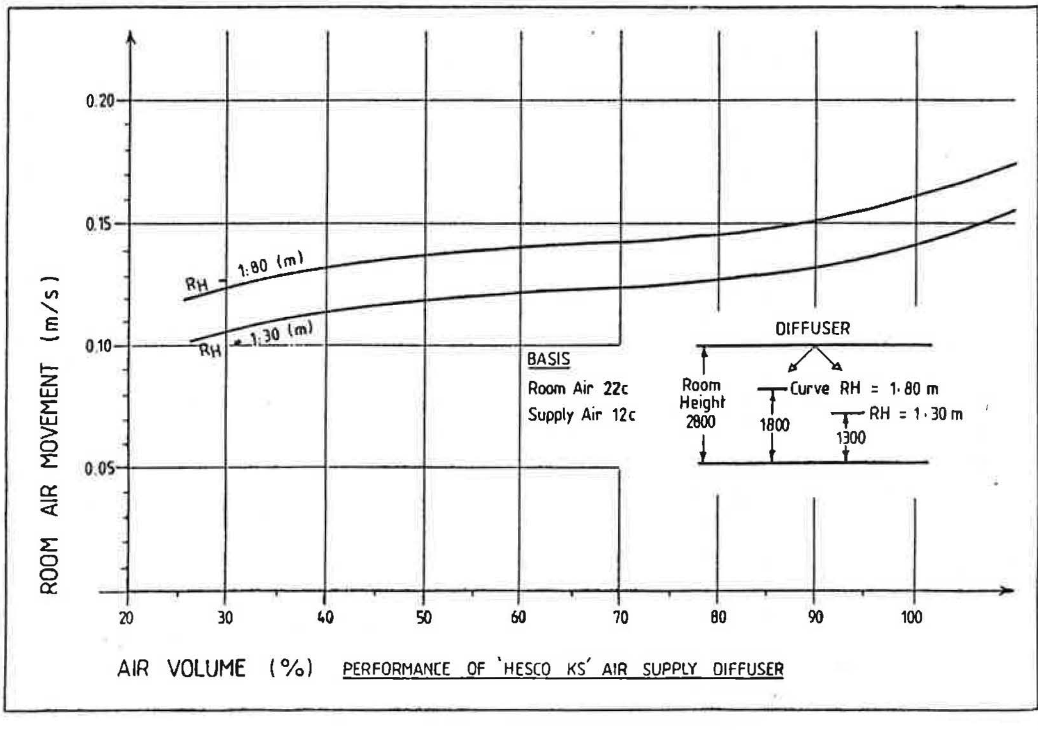
Performance of Hesco KS air supply diffuser

For Swiss diffuser maker Hesco, good draught-free comfort conditions will only be obtained if air movement in the occupied zone is maintained within the limits of 0.15 to 0.20m/s as recommended in the DIN 1946 standard.

To meet this requirement, it has developed a range of ceiling diffusers which, using a number of high induction jets, eliminate reliance on the "coanda" effect. They can be used in conjunction with a variety of irregular ceiling configurations where application of conventional slot diffusers would be problematical claims the company. In addition, satisfactory air movement will be achieved with the KS and SC diffusers on VAV systems even where the turn-down is 70%.

The accompanying test results from the Hesco laboratory on the KS type demonstrate this fact.

More information—circle 295



A Pressing Problem

Where different pressures have to be maintained between two rooms, either to stop nasties getting in to or stop them getting out, it is essential that any pressure change is detected as quickly as possible. Although instruments have been available to detect changes in ΔP for some time, until recently they have had to be re[illegible] regular intervals, using up a lot [illegible] worker-time. Included in the COSHH regulations is the stipulation that in this type of area there must be some sort of fixed pressure monitor, which could potentially increase costs for a number of companies. Most of these instruments suffer from zero drift which reduces accuracy and can lead to false alarms. Manual zeroing is no [illegible]blem on a hand held in[illegible]ent but is far from convenient on a unit that is mounted high on a wall.

Air-Neotronics has now introduced what it claims is the first automatic zeroing pressure monitor on the market. The Pressure Alarm* Monitor (PAM) uses the deflection of a sensor to detect pressure changes and every 30 seconds an electro-[illegible]atic valve isolates the sensor from the input so that the machine can check that it is reading zero: if it is not adjustments are made to compensate for the error.

When the unit detects a significant pressure change it can either set off an alarm or use its control function to change, for example, the speed of a fan. It can also be connected to a PC, datalogger or chart recorder so that documented proof can be provided to the authorities that the appropriate conditions have been maintained.

PAM is suitable for use in clean rooms and operating theatres and also has several applications in the general h&v field. These include the monitoring of air flow in vac systems and combustion air and stack draft in boiler houses. It will measure in a range of 0 to ± 1999 Pa to an accuracy of 0.1 Pa and can be used with a range of measuring devices including pitotstatic tubes, orifice plates and fixed pressure ports inside and outside containment areas. It can also be used to indicate when a filter needs changing because a blocked filter will bring about a reduction in pressure.

More information—circle 296

▸ 34 displacement ventilation, there is a risk that environmental tobacco smoke and other contaminants might stratify below the breathing zone if insufficient supply air is provided to feed the convective plumes. These contaminants may be entrained into the inhaled air by the supply jets. Sedentary occupants require around [illegible]s/s of outdoor air each to feed the plume generated by their own metabolism alone (2). Most systems of this type which have been installed over the last 20 years (mainly in Germany) have provided 6 to 10 litres/s of primary air at each seat. Most outlets have incorporated induction devices, so that supply air comprises a mixture of primary air and air drawn from low level in the r[illegible]

Figure 2 shows possible flow paths for tobacco smoke (a) evolving from a cigarette in an ashtray and (b) exhaled by a smoker, with a desk-mounted outlet discharging at approximately 70° to the horizontal. The amount of entrainment of smoke at desk level into the supply jet will depend on the distance of the s[illegible]e from the jet. In some cases [illegible]moke may be entrained into a neighbouring jet. This is a particular risk between adjacent seats in an auditorium.

Vortex-driven room air movement

A spiralling vortex can be generated within a controlled volume by discharging air tangentially to the outer boundary of the required vortex, and in the direction it is intended that the vortex should rotate. The apex of the spiral is defined by the position of an exhaust opening. This produces what is known as Rankine's combined vortex. Providing there are no disturbances, this provides a stable airflow pattern, with a steady movement of air towards the core of the vortex. Stability of the vortex depends on the velocity leaving the supply jets in relation to disturbing forces. Japanese experience (3) has found that most satisfactory operation occurs with minimum velocities in the outer part of the vortex of around 0.5 m/s. Velocities in the core, i.e. directly in line with the exhaust opening, will be significantly higher, approaching the face velocity at the opening.

'A SMOKING CANOPY TO SEGREGATE SMOKERS'

This phenomenon has been adapted by Swedish and Japanese manufacturers of ventilation equipment to industrial local exhaust applications such as fume cupboards, welding benches and open-surface vessels. More recently the Japan Air Curtain Corporation have developed a "smoking canopy" (see Fig. 3) for use as a segregated area for smokers, which can be incorporated into larger spaces in which smoking is not allowed.

A velocity under the canopy of 0.5 m/s is ideal for "capturing" contaminants, but may not be compatible with long term occupancy, particularly during the winter, when room temperatures are usually significantly lower than in the summer. For dissatisfaction below 10%, a temperature of 24–25°C is required for adapted people relaxing in winter clothing.

A spiralling vortex can be established in an enclosed space with a single plane surface jet to create the rotational movement and an exhaust opening to create the spiralling. Where there are no walls a set of 4 vertical supply ducts are required to form air curtains. The least migration of contaminants from under the canopy is found to occur when supply jets are directed inwards at an angle of 20° to the notional wall of the smoking area.

Velocity decay

Supply velocity (v_0) can be determined from an analysis of velocity decay in the jet to achieve the required minimum capture velocity (v_L) at a point half between two supply ducts (L), from the equation:

$$v_0 = 4.17\,L^{0.67}\,V^{L}$$

A typical canopy might have 44 mm diameter holes at a pitch of 100 mm, although designs will vary with the floor area covered and acoustic considerations.

This article has described three possible methods by which at least partial protection can be offered to non-smokers, without resorting to total exclusion of smokers from a building. Each has its disadvantages, however. Displacement ventilation and personal air supply offer some risk of exposure to non-smokers, particularly if cigarettes are left in ashtrays for significant periods. However this need not be a problem if non-smokers are sufficiently far from the smokers that a detectable concentration of tobacco smoke cannot be entrained into the plumes generated by their body heat.

The last system described comes the nearest to segregating smokers, without actually directing them into a separate smoking lounge. It might be adapted to smoking areas in bars, restaurants, staff rooms etc, where the relatively high velocity may not be a problem.

References

1. M. Sandberg and C. Blomqvist. Displacement ventilation systems in offices. ASHRAE Trans 5(2), 1989
2. P. Appleby. Displacement ventilation—A design guide. Building Services J. 11(4) pp 63–66, 1989.
3. Y. Nagasawa and S. Matsui. Application of spiral vortex flow in the control of indoor air quality. In: Ventilation 88, ed J. H. Vincent. Ann P-Occ Hyg. pp 413–422, Pergamon, 1989.