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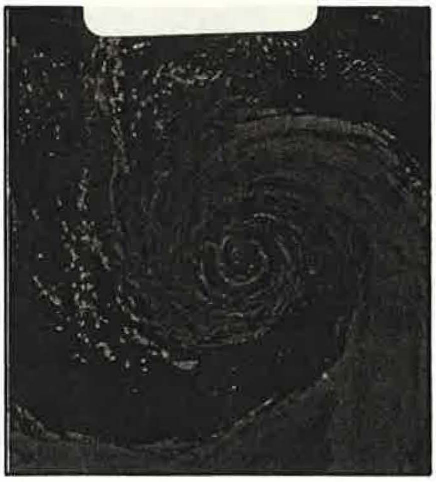
Ventilating for comfort



H E Martin argues the case for displacement ventilation as a way of ensuring air quality in an occupied space and details three methods open to the designer.

The purpose of ventilation is to provide good air quality indoors by removing contaminants and supplying clean outdoor air. The air is also frequently used as a heating or cooling medium to control the thermal climate. The system application, as well as varying demands for air quality and the thermal climate, have resulted in the design of different air distribution methods.

There are two ideal air flow patterns: total displacement air flow, in which the air flow is undirectional, spreading contaminants as little as possible; and total mixing air flow, in which the temperature and concentration of contaminants are evenly distributed within the room.

Several new concepts for stating the efficiency of the air distribution method have recently been proposed – ventilation efficiency as a measure of how quickly contaminants are removed from a particular zone in a room; and air change efficiency, which measures how rapidly air is being changed throughout the premises.

The displacement air flow technique is the fastest way to change air, achieving a coefficient of performance (cop) of up to 1·0. The corresponding highest figure obtainable with the mixing air flow technique is 0·5. The ventilation efficiency depends primarily on the type of polluting sources, and their location in relation to the breathing and occupancy zones.

Variations may therefore be large; and locally, the ventilation efficiency may actually become greater with mixing than with displacement air flow.

It is usually not enough to consider the premises as a whole, since supply air is normally intended for a particular part of the room. Air supplied to the premises, which fails to change old air in such a zone before it is exhausted, will cause the formation of a third type of air flow – short circuiting, which leads to a considerable reduction in ventilation efficiency.

In practice, there is rarely only one type of air flow pattern present at any one time. The various types of air flow will be more or less dominant in separate areas of the room, due to the combination of the following factors:

☐ location and design of the supply air device;
☐ velocity and temperature of the supply air;
☐ location of the exhaust air device;
☐ geometry of the room and its interior furnishings;
☐ and the type and location of thermal sources.

There is a risk of short-circuiting air flows in both displacement and mixing ventilation, particularly if the air paths have been poorly designed, or if furniture and fittings have been so arranged as to interfere with air mixing. It is possible to differentiate between three main air distribution methods:

☐ piston air distribution;
☐ jet-controlled air distribution;
☐ thermally controlled (source controlled) air distribution.

Piston air distribution is ideal for environments with very stringent standards for clean air, such as operating rooms in hospitals, and clean rooms in certain industries. Very high specific air flows allow a stable displacement air flow. Air is supplied at low velocity through the ceiling, floor or walls. It is distributed throughout the cross-section of the room, and forced through the premises (as by a piston) to the opposite side, where the air is exhausted together with the contaminants collected on the way.

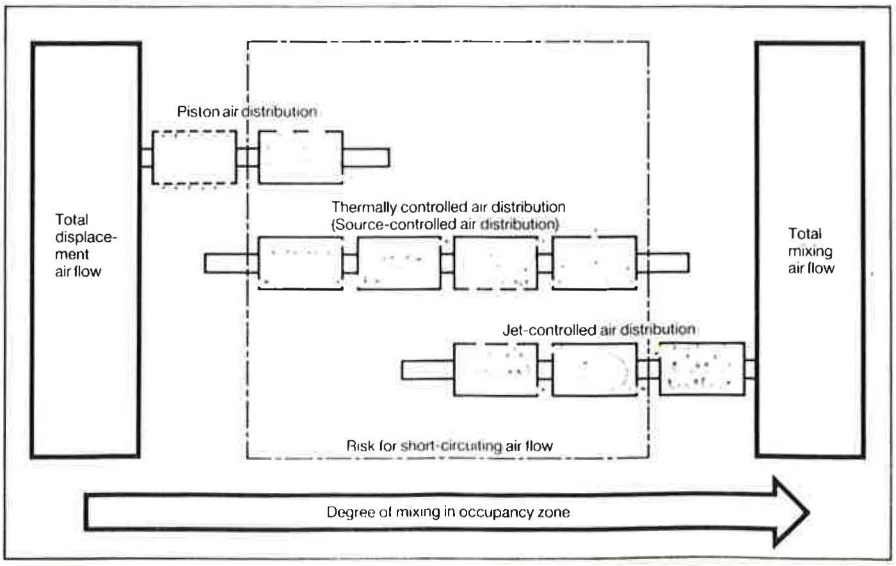
In the most common type of air distribution, air is supplied in one or more jets at high velocity. The air jets pull ambient air along and their velocity and direction is adjusted to mix supply air and room air effectively without causing drafts. There are a number of ways to supply the air to create various types of mixing air flow patterns in a room. This type of air distribution is therefore frequently designated as mixing ventilation.

In cases in which air quality is a concern, the method is also referred to as "diluting" ventilation.

With total mixing, the concentration of contaminants in the air will be completely uniform in the room and the pollutant content will be determined solely by the generated quantity and the specific air flow.

Air in the premises is therefore "diluted" with supply air and, as mentioned earlier, this type of air flow does not permit high ventilation and air change efficiencies. But it is less sensitive to disturbances and, consequently, more reliable.

Below: The choice of an air flow pattern will depend on the requirements for air cleanliness and the quantity of contaminants produced in the premises. The required amount of ventilation air will vary within a wide range.



Schlieren photograph of a naturally occurring jet-controlled air distribution; in this case a stream of air created by a human cough.

When displacement air flow patterns dominate the occupancy zone, this is usually described as displacement ventilation.

Heat cannot be supplied with the thermally controlled method, since overtempered supply air will rise directly towards the ceiling and have a strong short-circuit effect.

When the standards for clean air are very high, ie in clean rooms and operating rooms, the choice is simple: piston flow distribution.

In applications with a considerably lower ventilation requirement such as housing and storage facilities, where even temperature is a priority, the selection is also easy: jet-controlled air distribution. If, on the other hand, it is a question of applications with major ventilation needs and strict requirements for thermal comfort, the choice between jet-controlled and thermally controlled air distribution is not obvious. In these cases, the ventilation system generally covers the climate function as well (cooling and/or heating).

Thermally controlled air distribution comes into its own when many contaminants are produced in combination with surplus heat, provided that possible disturbances are minor, and that there is sufficient room to accommodate supply air devices.

Jet-controlled air distribution, in contrast, will be most effective when very few contaminants are produced in the premises, regardless of whether there is a need for heating or cooling. It also allows great flexibility in locating the devices.

By matching the various features of the methods with specific demands in different specifications, a simple selection guide can be produced. The different air distribution methods all have their advantages and disadvantages which have to be weighed according to their importance for each individual application. To ensure a good indoor climate in a building, the choice of air distribution method has to be considered very carefully during the design stage.

The greatest advantage of jet-controlled air distribution is that cooling, as well as heating, can be introduced together with the supply air while retaining small temperature gradients in the room – even if there is a risk of short-circuiting air flows when over-tempered air is supplied.

In recent years, much attention has been paid to a technique in which the air distribution is controlled by thermal forces from heat sources located in the premises.

This source-controlled method has been developed to achieve a higher air change efficiency in premises using general ventilation, and containing heat sources that produce contaminants.

The supply air, somewhat undertempered, is supplied "diffusely" at low velocity at floor level. It then flows out over the floor and is conveyed up to ceiling level by means of upward convection currents emanating from heat sources. The air is exhausted at ceiling height.

Since ordinary specific air flows in both comfort and industrial applications correspond to piston velocities below 0·01 m/s, a very weak displacement air flow is obtained in the lower part of the premises, with some elements of strong convection currents.

Stable air distribution at such low velocities thus requires cooling coupled with undertempered supply air and subsequent vertical temperature stratification.

A mixing air flow, produced by convection currents from heat sources, is obtained in the upper part of the premises.

The relationship between the total strength of the heat source and the size of the supply air flow will determine how far the mixing will penetrate down into the premises and, thereby, the extent to which mixing will be attained in the occupancy zone.

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