Application of Low Level Airconditioning Systems in Tropical Climates

Low-level ventilation systems can, if designed appropriately, reduce cooling loads and improve indoor air quality. They work more effectively than conventional mixed flow systems for smoke control in the event of a fire and since the floor-to-floor height can be reduced, building costs can be saved.

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For the purpose of definition, low-level ventilation systems discussed in this article include both under-floor ventilation systems and displacement flow systems.

Under-floor ventilation systems are becoming increasingly popular with the advent of information technology. This type of system has been in place for more than 15 years notably in the USA, Europe and South Africa. In East Asia, the Hong Kong and Shanghai Bank in Hong Kong is probably the first to implement this system for comfort air conditioning.

In Malaysia, under-floor ventilation systems have been utilised strictly for cooling in conventional computer rooms for the past 20 years. Lately, three notable projects in Malaysia, namely the new Securities Commission Building, the new Malaysia Telecom HQ known as the 'Menara Telekom' and the Ericsson Building in Cyberjaya, have utilised under-floor ventilation systems for comfort cooling application.

Displacement flow ventilation has been employed for industrial application for many years, particularly in Scandinavia. This system has also recently gained popularity for comfort cooling in office buildings.

Both types of systems are known to provide better thermal comfort and indoor air quality compared to the conventional mixed flow system.

Comparison between Mixed Flow and Low Level Ventilation Systems

Mixed Flow System

For a conventional ventilation system with ducted air distribution, cooled air is introduced into a room at high level normally at the ceiling. And in like manner, the stale and contaminated air in the room is also extracted at ceiling level via a separate system. This is generally known as a 'balance' system (refer to *Figure 1*).

As cooled air is introduced into the room, it mixes with the contaminated air in the room, and therefore lowers the airborne contaminant concentration and the room temperature to an acceptable level. This mixing action evens out the temperature gradient and contaminant concentration in the room.

This is a rather uneconomical and inefficient way of maintaining thermal comfort and good indoor air quality, particularly if the floor to ceiling height in the air-

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conditioned space is typically at 2.7m or higher.

Displacement Flow System

For a displacement flow system, cooled air is supplied into an enclosed space at floor level, using displacement flow diffusers. The supply air enters the room at a low velocity, normally around 0.4m/s with a temperature difference between 1 to 6°C below the surrounding room air temperature. The incoming cooled air will drop to floor level and gradually move across the room, picking up any local heat source which will produce an upward convective plume whilst carrying with it any airborne contaminants (refer to *Figure 2*). This way, a higher air temperature and airborne contaminant concentration will be maintained above the occupied zone due to convective forces and the air is exhausted at ceiling level. For this system to work effectively, the following conditions must be met :

- The floor to ceiling height should be 2.7m or higher. The higher it is, the more effective the system will be.
- There must be an adequate local heat source to generate the convective forces. Surface temperature of the heat source should be greater than 35°C.
- Supply air temperature must be lower than the surrounding room air temperature.
- Airborne contaminants must be sufficiently small (typically smaller than 10 microns) to be carried upwards by convective forces.

If these conditions are met, equivalent comfort conditions with better indoor air quality can be achieved with lower airflow rate and higher supply air temperature using the displacement flow system when compared to the conventional mixed flow system (refer to *Figure 3*). Therefore, there will be a

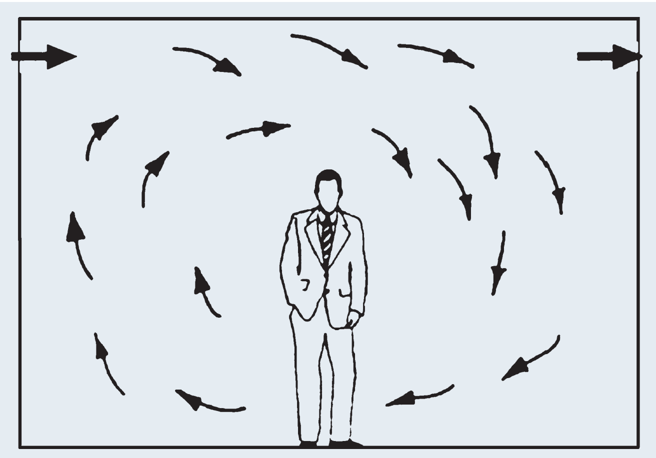

Figure 1: Mixed Flow Ventilation

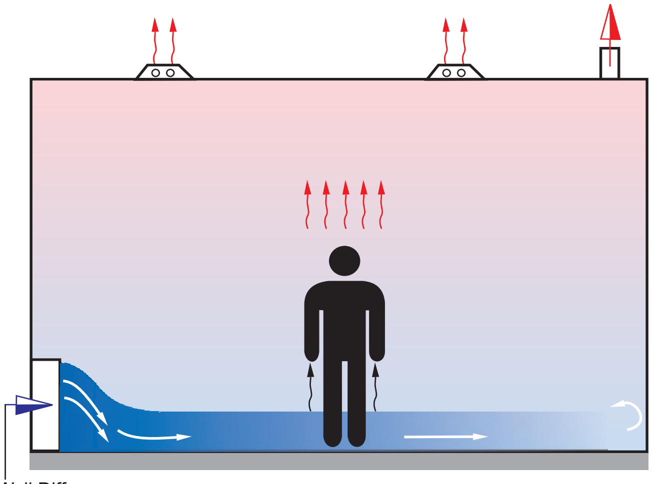

Figure 2 : Displacement Flow Ventilation

significant energy savings and a smaller chiller plant will be needed to provide the required cooling.

Under-floor Ventilation System

With this system, as the name suggests, cooled supply air is introduced into the floor void of a raised floor system and distributed to the workspace above via air terminal devices (refer to *Figure 4*). These can be in the form of linear bar grilles, which are commonly used in computer rooms, mainly for sensible cooling, or induction type swirl floor diffusers for the occupied space, which are better suited for comfort cooling.

Typical floor void height is between 300 and 600mm, which is also used for electrical services distribution and IT network system. Such a height is necessary to ensure that the electrical (and any other) services do not interfere with the airflow. The exact height required can only be determined by carrying out detailed coordination of all the services that are routed through the floor void.

Fan-powered floor units can also be incorporated to accommodate the perimeter zone cooling requirement where the heat gain is likely to fluctuate and is much higher.

To ensure uniform airflow through the floor void, a floor area of 300 to 500 square meters (depending on the building configuration) can be easily and adequately pressurised by a single supply air duct. Multiple supply duct outlets may be necessary for larger floor area.

Design Considerations for Low Level Ventilation

Supply Air Conditions

With low-level ventilation, supply cooled air is generally introduced into the occupied space at

continued on page 78

continued from page 76

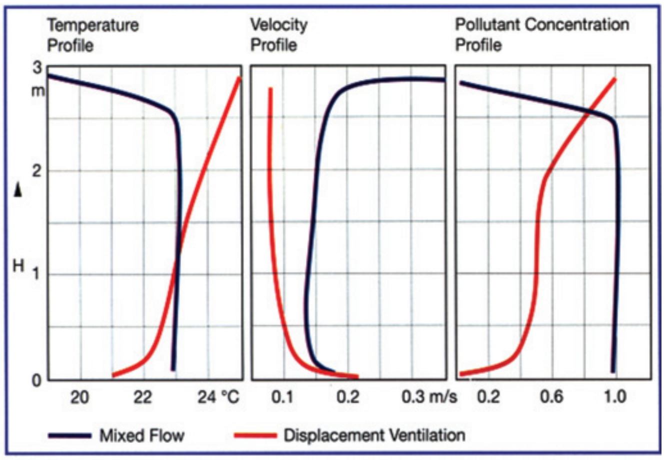

Figure 3: Comparison of performance between mixed flow and displacement flow ventilation systems.

finished floor level through floor diffusers or displacement flow diffusers along the wall perimeter. Therefore, for comfort cooling applications, the velocity and temperature decay characteristics of the diffusers or the discharge velocity and the supply air temperature are important features of a successful design.

For displacement ventilation, the discharge velocity of the supply air should not exceed 0.4 m/s for comfort cooling application, and the height of the diffusers should not exceed 0.8m. For industrial applications, depending on the design requirement, discharge velocity of up to 1 m/s is possible without limiting the height of the diffusers.

With under floor ventilation, the floor swirl diffusers are designed to provide rapid temperature and velocity decay by induction in order that the "discomfort" zone of the diffuser is kept as small as practicable. Typically, they should be located at least 400mm away from the seating area.

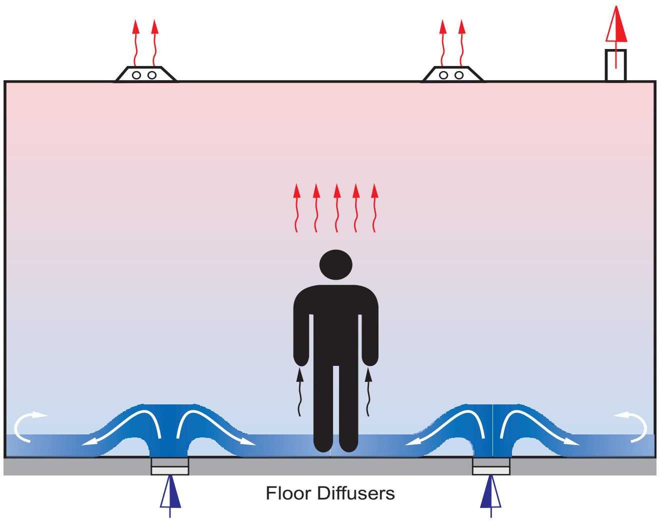

Figure 4: Under-floor Ventilation

Supply air differential temperature for low level ventilation systems is typically around DT of 4 to 6°C below the design room temperature.

This is much smaller than the supply air differential temperature for the mixed flow system, which is typically around a DT of 10°C.

This means that designers may require a higher airflow from each diffuser for buildings in a tropical climate than their contemporaries in a temperate climate.

As a guide, the supply air temperature as recommended by BSRIA (Building Services Research and Information Association of UK) may be selected as follows:

	Supply Air Temp. (°C)
Sedentary Occupation	18 to 20
More active	17 to 19
Industrial application	15 to 17

Designers should consult the manufacturer for the aerodynamic data of their product. A mock-up test can be set up in an aerodynamic test laboratory that matches the actual built environment to verify the accuracy of the predicted results using the manufacturer's data. Such a test was carried out for both the Securities Commission Building and the Menara Telekom projects in Malaysia as mentioned earlier.

Airborne Contaminants

Airborne contaminants can be loosely classified based on the phase or physical state of the suspended particles (ie., solid, liquid or gas) as indicated below:

- Dust; such as smoke particles with an average size of 0.1 to 0.3 µm and bioaerosols such as pollens (typically between 10 to 100µm in diameter), fungus spores (10 to 30µm) and bacteria (0.4 to 5µm).
- Mist; fog and steam. Tobacco smoke consists of suspended liquid particles typically between 0.01 and 1.0µm.
- Vapour gases and smog, which normally refers to air pollution.

Particles less than 0.1µm in diameter behave quite similar to gas molecules, traveling with Brownian movement with no predictable or measurable settling velocity. Particles between 0.1 and 1.0µm have very low settling velocity which can be regarded as negligible because normal air current will counteract any settling. This air current will still keep particles of up to 10µm diameter in suspension for an

continued on page 80

continued from page 78

appreciable time span.

It should be noted that in most commercial buildings, over 99% of the particles in the typical atmosphere are below 1µm according to ASHRAE Fundamentals Handbook 1997. Particles larger than 10µm will settle fairly rapidly and can be found suspended in air only at source or under the influence of strong wind.

If most pollutants are larger than 10µm and are therefore unlikely to be carried by the upward convective force, a low level ventilation system will not be effective in maintaining good indoor air quality.

Air Leakage

An air leakage test for the raised floor systems and the electrical terminal boxes was carried in a controlled environment by the consultant in conjunction with the manufactuters for the new Securities Commission building. The consultant had specified a maximum leakage rate of 20 l/min. per linear metre at 50 Pa for the raised floor system. A final mock-up test was carried out on site to determine the overall leakage rate of the installation.

The control of air leakage rate is of importance for under floor ventilation to maintain the required floor void pressure for the diffusers to deliver the required airflow rate. In an extreme case, condensation could occur along the external wall due to infiltration of the humid outdoor air if adequate precaution is not taken.

For displacement ventilation, this should not be an issue since the existing standards for ductwork fabrication and installation are adequate to limit the air leakage rate.

Condensation Assessment

Assessment of the risk of condensation was carried out for the external wall structure and both the ground floor and intermediate floor slab for the Securities Commission building. From that, it was concluded that as long as the supply air temperature is maintained at 17°C or above, the risk of condensation is negligible.

Fire Safety

All electrical cables in the floor void should be tested to acceptable national or international standards to ensure that they meet acceptable fire performance standard/code.

Plastic components of the floor swirl diffuser units are also made from fire retardant material.

It is a requirement under the Malaysian Building Regulations, to provide a mechanical smoke spill system if the total floor area of the building exceeds 929m^2 (or 10,000 ft^2). In the case of the Securities Commission building, smoke detectors are provided in the 400mm deep floor void.

Cleanliness of Ventilation System

Existing standard(s) for cleanliness of duct systems should be applied to the floor void where practicable when it is applied to under floor ventilation system. However, it is recommended that studies should be carried out on the long-term implication of under floor ventilation and, how best to maintain the cleanliness of the floor void such that the indoor air quality is not compromised through time.

Advantages and Limitations of Low Level Ventilation

Displacement Flow

An equivalent comfort condition with better indoor air quality can be achieved with higher supply air temperature and possibly with lower air flow rate using low-level ventilation (i.e., including under-floor ventilation) when compared to the conventional mixed flow system. Therefore, a significant energy saving can be achieved and a smaller chiller plant will be needed if the floor to ceiling height is greater than 2.7m and adequate local heat source is present to generate the convective force.

The displacement flow diffusers are usually located at floor level and they are generally quite bulky. Therefore, if the sensible heat load is very high, there may not be enough room to install these diffusers. They should be located strategically to ensure good air distribution, away from obstruction and areas where it is prone to mechanical damage.

Both displacement flow and under-floor ventilation systems work more effectively than conventional mixed flow systems for smoke control application in the event of a fire.

Under-floor Ventilation

Under-floor ventilation is only viable economically if there is a need for raised floor system. The floor void can be utilised to distribute supply air to the occupied zone and hence, there is a cost saving on the distribution ductwork installation.

The raised floor system also offers the building owner/user the flexibility to relocate the supply air outlets to suit new furniture layout without much

continued on page 82

continued from page 80

disruption in the work place. In addition, it will improve the indoor air quality of the occupied space.

The clear ceiling void space can be reduced to its minimum to allow for cable trunkings or conduits, piped services and possibly return air ducting. Therefore, the slab-to-slab floor height can be reduced by about 300 mm per floor compared to buildings with a conventional mixed flow system. As a rule-of-thumb, this could translate to a cost saving of one floor for every twelve floors to be built.

Similar to the displacement flow system, it is possible to have a significant energy saving with under-floor ventilation if the floor to ceiling height is greater than 2.7m

Typical cooling output for each floor diffuser is between 130W (i.e. equivalent to 18 l/s from a 150 mm dia. diffuser at 25 Pa; NC 25) and 250W (i.e. equivalent to 34 l/s from a 200 mm dia. diffuser at 25 Pa; NC25) at a DT of 6°C. If the cooling load is very high, it may be impractical to use floor diffusers without the assistance of fan powered floor units.

It is recommended that the floor diffusers should only be located within the circulation area. Room furnishings should be arranged such that they do not obstruct the airflow.

Concluding Remarks

Like all new technologies, low-level ventilation systems will pose new challenges to the designers, manufacturers and local authorities. Architects and builders will have to review their construction methods and standards together with the building authority, for example to construct buildings with lower air leakage rate and higher thermal properties to conserve energy.

The Building Services Research and Information Association (BSRIA) in the UK has suggested that the key to successful design of a low-level ventilation system is:

- To select the correct supply airflow rate "to maintain the flow boundary at a sufficiently high level in the room and to avoid excessive temperature gradient" in the occupied space, typically no greater than 3K per metre in height.
- To specify the "supply air conditions (i.e., temperature and cleanliness which are close to that required in the occupied space".

It is questionable if low-level ventilation is compatible with a Variable Air Volume system since the supply airflow rate required to maintain an acceptable comfort condition in the occupied space is NOT so directly related to the internal heat gains.

A low level ventilation system is particularly suited for an atrium, airport terminal and an industrial application where the floor to ceiling height is high, cooling requirement is predominant and the airborne contaminants to be kept under control are sufficiently small for the system to operate effectively.

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